LED Lighting System for Rolling Stock

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OVERVIEW: With energy efficiency becoming increasingly important in recent years, demand is growing for the adoption of LED lighting as a replacement for fluorescent interior lighting in passenger trains. Rather than simply replace fluorescents with LED lighting, Hitachi has drawn on its experience and past activities as a manufacturer of rolling stock to achieve power savings of 40 to 60% while also taking account of interior design considerations and the color of the light. Hitachi has also succeeded in approximately halving life cycle costs compared to existing general-purpose LED lighting through measures that include adopting a dedicated power supply and designing long-life circuits. In the future, Hitachi intends to continue development with the aim of adopting LEDs for train headlights and other lighting with systems that further enhance the functions of LED lighting for passenger train interiors.

INTRODUCTION

SINCE 1997, Hitachi has been developing and marketing its A-train rolling stock based on its own proprietary concepts. Recently, more than a decade later, in addition to specifications, design, safety, recycling, and maintenance, there is also a strengthening demand for the adoption of eco-technologies that are kind to people and conscious of the environment. Given the growing need for a shift from fluorescents to light-emitting diode (LED) lighting in passenger train interiors, rather than simply adopting general-purpose LED lighting, Hitachi has drawn on its experience and past activities as a manufacturer of rolling stock to develop LED lighting specifically for use in trains that complies with railway-specific standards, including for testing.

With new technology and product development in recent years, there have been numerous instances where problems that have inhibited commercialization have arisen from differences in philosophy and understanding between the people who operate these products and technologies and the people who produce them. Taking account of this, Hitachi went back to the basic principles of manufacturing in the development of this lighting system and embarked on a product development that involved combining technologies learnt from past mistakes with the latest new technologies, undertaking this through the development of the LED lighting system for rolling stock.

This article describes the purpose and features of LED lighting, LED interior lighting for rolling stock, and LED lighting systems.

PURPOSE AND FEATURES OF LED LIGHTING

Features of LED Lighting

The features of LED lighting systems are listed below.

(1) Lower power consumption

LED lighting typically provides a simple replacement for previous types of lighting; is said to roughly halve energy costs and carbon dioxide (CO_2) emissions; and represents a simple, effective, and significant measure for implementing laws such as the Act on the Rational Use of Energy (law relating to the rationalization of energy use) and the Law Concerning the Promotion of Measures to Cope with Global Warming (law encouraging measures for preventing global warming).

(2) Elimination of flickering

LED lighting is ideal for use in trains because it is powered by direct-current (DC) electric power and does not produce the flickering that occurs with fluorescent lighting. This should reduce eye strain.

(3) No emission of ultraviolet rays

As the spectrum of light produced by an LED depends on the semiconductor and phosphor material, unlike most other light sources such as fluorescent and incandescent lighting, it does not include any of the ultraviolet or infrared rays that do not provide any illumination. Similarly, it is also less prone to attracting insects because it produces very little ultraviolet light in the part of the spectrum visible to insects. In outdoor as well as indoor lighting applications, not having to worry about insects means

that a feature of LED light fittings is that they are less prone to becoming dirty.

(4) Reduction in life cycle costs

As the life of an LED element is approximately 40,000 hours, it significantly reduces the work associated with the frequent replacement, lighting on/off control, stock control, and waste disposal tasks that are an issue for halogen, fluorescent, and other forms of conventional lighting. The lifetime of an LED lighting system is defined as the point at which the brightness falls to 70% of its initial level. As the principle of operation of LED lighting systems means that they are not subject to the phenomenon of burn out that occurs on halogen and fluorescent light bulbs, they do not need to be replaced before reaching their design life. Similarly, it is not necessary to keep spares on hand in case of light bulbs burning out.

Installation Requirements for LED Lighting System for Rolling Stock

The requirements for use of LED lighting systems in rolling stock are: (1) Functionality (safety), (2) Reduction in power consumption, (3) Design, (4) Maintenance, (5) Consciousness of the environment. Only once these five requirements have been satisfied can the lighting system be adopted, and it is also necessary to have an adequate understanding of each railway company's equipment and the conditions in the trains where the lighting system will be installed, particularly regarding safety considerations.

Philosophy behind Lighting Level Standards

A mandatory requirement is to satisfy the criteria in JIS E4016 ("Illuminance for Railway Rolling Stock—Recommended Levels and Measuring Methods"), the Japanese Industrial Standards (JIS) for lighting levels in rolling stock in Japan. For passenger train interiors, the standard stipulates 200 lx or more at a height of 850 mm above the floor. The wavelength of LED light (roughly 450 to 500 nm) is shorter than that of fluorescent light (roughly 550 nm), and this gives it a characteristic bluish tint. Because the light is whiter than fluorescent lighting with an emission intensity about 1.3 times stronger, text and similar on illuminated objects have a crisper appearance than when fluorescent lighting is used.

Interdependence of Illumination Intensity and Angle of Spread

Because it is produced in a discharge tube, fluorescent lighting has a spread of 360°. In contrast, the angle of light spread for typical LED lighting is approximately 120°, only about one-third that of fluorescent lighting. This means that, compared to fluorescent lighting, there is little illumination intensity to be gained by using a reflector with an LED light.

The indirect LED lighting developed and adopted initially was designed to have a spread of 140°, which is 20° more than normal LED lighting, and the newly developed direct lighting has increased this to about 173°.

INTERIOR LED LIGHTING FOR ROLLING STOCK

Improving Energy Efficiency of Interior LED Light Fittings

Although LED lighting is already more energy efficient than fluorescent lighting, Hitachi has proceeded with development aimed at reducing power consumption further. As the intensity of LED light is roughly proportional to the electric current, Hitachi has established circuit designs and devices that keep the current low without loss of light intensity. Also, the sheet selected for light diffusion is one that has a high level of transparency while still retaining its ability to diffuse light. The result, from data on use in actual rolling stock, is an approximate 40 to 60% reduction in power consumption compared to fluorescent lighting.

Lengthening Life of Interior LED Light Fittings

As has already been noted, general-purpose LEDs typically have a life of 40,000 hours. The newly developed LED features circuit and board configurations that are resistant to the effects of heat and designed for long life, giving it a life of 100,000 hours (16 years). Both the 100-V DC emergency lighting power supply and the 200/254-V alternating current (AC) power supply have shapes that are compatible with fluorescent light fittings. The entire light fitting was developed to have a long life, with the power supplies being designed especially to use long-life components to give them the same 100,000-hour (16-year) life as the LED devices.

LED Lighting with Strong Yellow Component

A feature of its technology for being gentle on the eye is that the newly developed LED lighting system for rolling stock incorporates a technique for synthesizing and amplifying light that uses the inherent properties of light without using an LED diffuser lens. Hitachi has also developed leading-edge

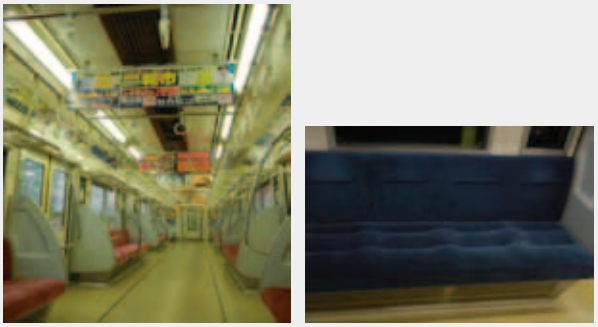

Fig. 1—Train Interior Using Conventional Fluorescent Lighting and Blue Seat.
This shows the train interior with fluorescent lighting prior to refurbishment, and priority seating for the elderly and people with disabilities.

Fig. 2—Train Interior Using LED Lighting with Strong Yellow Component and Blue Seat.
This shows the train interior after refurbishment with light-emitting diode (LED) lights with a strong yellow component, and priority seating for the elderly and people with disabilities. The vivid blue coloring is highlighted.

technology for producing white light with a high level of color rendering properties that mixes blue, yellow, red, and green from the three primary colors (red, green, and blue). This technology has been deployed in LED lighting on trains (see Fig. 1 and Fig. 2).

Structure of Interior LED Light Fitting

The most recently developed LED light fitting has a design that allows it to be used in any train and which requires the minimum amount of work for retrofitting into refurbished trains. The design also features an aluminum base for the LED circuit board, and the ability to change the light cover to suit the specific design of the train.

Maintenance has also been improved by the use of a replaceable LED circuit board to allow for future LED upgrades. The design allows the entire circuit board to be unplugged from the connectors and replaced as a single unit (see Fig. 3).

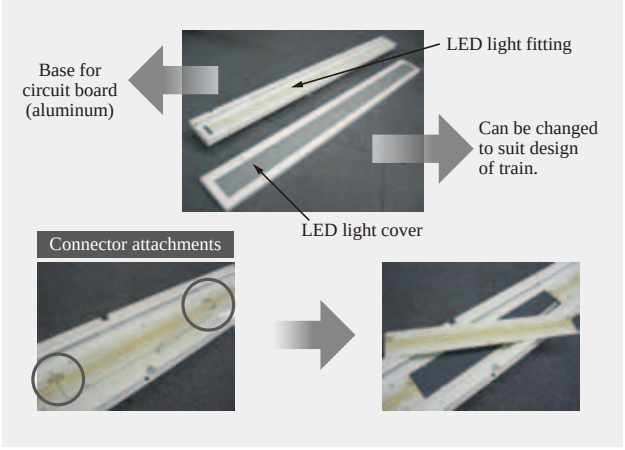

Fig. 3—LED Light Design and LED Circuit Board.
The light fitting in which the circuit board is installed is made of aluminum and the cover is made of toughened glass over which is spread a highly transparent diffuser sheet. The LED circuit board is designed for easy replacement of individual blocks.

Example Installation of Interior LED Light Fitting

The following sections describe the use of the above LED technology both in the refurbishment of existing trains and subsequently in new trains, beginning with its use in indirect lighting. The first LED lighting system for rolling stock was introduced on Hankyu Corporation's Series 9000 trains. This installation used quasi-indirect lighting and the initial type of LED (see Fig. 4).

Next, direct lighting using LEDs with a strong yellow component was installed in refurbished Series 8000 trains of Keio Corporation. These lights have been positioned so as to emit light from the side of the compartment to illuminate the advertising along each side of the ceiling (see Fig. 5).

A direct lighting system has been installed in new Series 817 trains for the Kyushu Railway Company. The system is an LED version of a form of lighting that attaches to air conditioning vents and allows

Fig. 4—Indirect LED Lighting for New Series 9000 Trains Supplied to Hankyu Corporation.
These initial types of LEDs first installed by Hitachi in rolling stock were positioned perpendicular to the floor. The color temperature was selected to produce light of the same color as the previous fluorescent lighting.

Fig. 5—Direct LED Lighting Installed in Refurbished Series 8000 Trains Supplied to Keio Corporation.
Direct LED lighting was installed as a replacement for the previous fluorescent lighting. Being flatter than the fluorescent lights they replace, the LED light fittings create a more open ceiling space.

Fig. 6—Direct LED Lighting Installed in New Series 817 Trains Supplied to Kyushu Railway Company.
These interior ceiling lights installed in a typical A-train provide a simple and expansive interior space.

the interior of the train to be made larger, one of the features of the A-train (see Fig. 6).

LED HEADLIGHTS IN ADOPTION OF LED LIGHTING SYSTEM

Rolling Stock Headlights

Currently, halogen lamps or high-intensity discharge (HID) lamps are used for train headlights to improve forward visibility. However, these need to be replaced annually, and in the worst cases, once every three months. Because of their importance for ensuring safety, headlights must be replaced immediately if they fail, but this is a time-consuming job. For these reasons, not only do headlights need to provide excellent visibility and have a long life, they must also be easy to replace or upgrade. Fig. 7 shows the structure of a lighting unit.

Features of LED Headlights

Hitachi has drawn on know-how from development of interior lighting to achieve energy efficiency, reliability, long life, and ease of installation. This involves reducing power consumption by 70% to improve energy efficiency, using lenses proven in other products to ensure reliability, and conducting more than four years of exposure testing to select

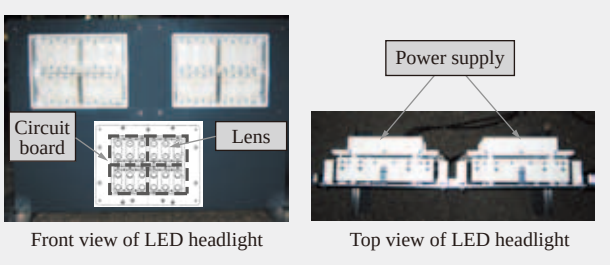

Fig. 7—LED Headlight Design.
The headlight is split into four blocks. The upper blocks are mainly used for high beam and the lower blocks for low beam. The power supply is fitted behind the lights.

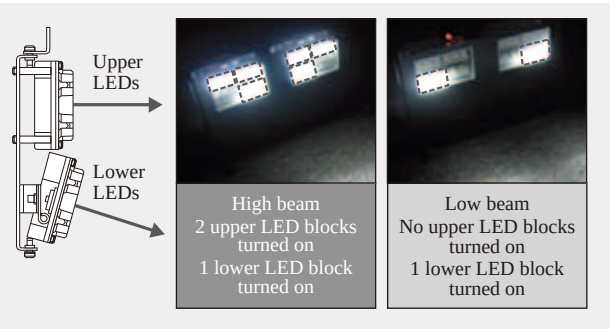

Fig. 8—High and Low Beam Operation.
The high beam light uses the two upper blocks and one lower block. The low beam light uses one lower block. If one block fails, the system can switch on an adjacent block as a replacement.

plastics that do not degrade under ultraviolet light. Redundancy has also been improved by using the high beam LEDs to provide a backup circuit for use in the event of the failure of the low beam LEDs (see Fig. 8).

FUTURE LED SYSTEM DEVELOPMENTS

The following sections describe the potential future developments for the LED system.

(1) Adoption of common power supply

Two separate power supplies are used at present, an AC power supply and an emergency DC power supply. By adopting a single power supply, there is scope for measures such as consolidating the power supply units or operating all lights from batteries during an emergency to reassure passengers. Consolidating the power supplies will also make replacement easier and reduce costs.

(2) Modularization of ceiling-mounted equipment

Integrating other equipment such as internal ceiling cabling, radio transmitters, or speakers into the LED light fittings will not only simplify the ceiling design, it will also improve reliability and shorten lead times by making installation easier.

(3) Integration with monitoring equipment

Within the time, distance, and other constraints placed on monitoring equipment, the optimum lighting level can be varied depending on factors such as the time of day or whether the train is passing through a tunnel, with potential benefits including enhanced passenger comfort and further improvements in energy efficiency.

CONCLUSIONS

This article has described the purpose and features of LED lighting, LED interior lighting for rolling stock, and LED lighting systems.

Although more expensive than previous forms of lighting such as fluorescent and HID lamps, it is anticipated that LED lighting systems will be used increasingly in the future as mass production brings down costs, and because of their superior life cycle costs due to better energy efficiency and longer life. Rather than limiting use of LEDs to merely a replacement for existing lighting, Hitachi intends to continue developing and designing rolling stock systems for easier maintenance and superior energy efficiency in order to provide operators with efficiency improvements while also improving passenger comfort by taking account of the entire rolling stock system.

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