Featured Articles

Development of 10000 Series Rolling Stock for Tokyo Monorail

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OVERVIEW: The 10000 Series rolling stock for the Tokyo Monorail is a replacement for the 2000 Series that has been in use for the last 17 years. By adopting the latest technologies and a design in harmony with the surrounding area, the development has succeeded in building rolling stock that features: (1) expanded services (four-language multilingual information service utilizing the cars' LCD displays, provision for oversize luggage, and barrier-free accessibility), (2) car design enhancements (exterior that harmonizes with surrounding area, Japanese-themed interior), (3) better environmental performance (use of LEDs for headlights and interior lighting, use of unpainted rolling stock), and (4) greater safety (installation of rolling stock information and control systems for driving control, indicator lights for doors that are opening and closing, barrier-free format for side display units, longer battery operation).

INTRODUCTION

TOKYO Monorail celebrates its 50th anniversary this year, having commenced operation on September 17, 1964 on the eve of the Tokyo Olympics. With the second Tokyo Olympics to take place in 2020 and an increasing number of international flights using Haneda Airport (Tokyo International Airport), Hitachi has developed the 10000 Series rolling stock with the aim of building the monorail cars that will serve as a gateway to Japan. The new rolling stock uses Hitachi's A-train technology optimized for use on monorail cars.

This article describes the development concept behind the 10000 Series rolling stock and the results of development.

LINE OVERVIEW

The Tokyo Monorail runs for 17.8 km between Monorail Hamamatsucho Station and Haneda Airport Terminal 2 Station, also stopping at Haneda Airport International Terminal Station. The monorail can run the length of the line in as little at 19 minutes, with services leaving at 3 minute 20 s intervals during peak hours. Used by a wide range of people including local commuters and airport users, it has a capacity of roughly 10,000 passengers each way during peak hours and roughly 300,000 people over a full day (2010 figures).

From Monorail Hamamatsucho Station to Tennozu Isle Station, the monorail runs past central-city offices and residential buildings and offers views of Rainbow Bridge and Odaiba. From Tennozu Isle Station and Ryutsu Center Station, it runs parallel to the Shutoko Metropolitan Expressway, offering views of the Keihin Canal and nearby parkland as it passes by them at high speed. Along the way it passes Showajima Station, where a siding was built in 2007 to allow the first monorail express services to be operated. From Seibijo Station to the terminus at Haneda Airport Terminal 2 Station, it follows an undulating course with views of the airport runways and of Mount Fuji and Umihotaru in the distance. Accordingly, although Tokyo Monorail is an urban line, it also gives passengers a sense of sky, sea, and parkland.

ROLLING STOCK

Specifications

Table 1 lists the main rolling stock specifications and Fig. 1 shows the layout and dimensions.

Carbody Structure

The carbodies are built from lightweight and easily recyclable aluminum alloy, using friction stir welding (FSW) to minimize welding-induced distortion. This results in attractive cars that do not require painting.

TABLE 1. Rolling Stock Specifications
While the specifications are based on the existing 2000 Series, a low-voltage power supply has been added to handle the addition of numerous devices.

Parameter	Specification	
Type	Straddle-beam electric monorail with dual-axle bogie made of aluminum alloy	
Cars per train	6 (3 cars per unit)	
Capacity	76 people/car	
Power system	DC750 V	
Rail width	800 mm	
Load	Axle load (max.) 90.2 kN	
Performance	Acceleration: 0.97 m/s^2	
	Deceleration	Normal: 1.11 m/s^2
		Emergency: 1.25 m/s^2
Maximum gradient	60‰	
Minimum curve radius	100 m	
Main motor	Three-phase squirrel-cage induction motor	
Control system	Two-level IGBT, VVVF inverter	
Brake	Regenerative brake and electrically operated electromagnetic straight brake with pneumatic-hydraulic converter	
Electric air compressor	Oil-free reciprocating	
Signals and safety	ATC/TD	
Communications	150-MHz band, space-wave semi-duplex	
Low-voltage power supply	124 kVA SIV (two per train)	
Current collector	Via contact with underside of electrified rail	
Air conditioning	Roof-mounted with two-stage control: 20.3 kW/unit	
Emergency escape	Escape chute, abseil	

DC: direct current IGBT: insulated-gate bipolar transistor
VVVF: variable voltage variable frequency
ATC/TD: automatic train control/train detection SIV: static inverter

Furthermore, because of the need to satisfy stringent axle load limits despite the addition of extensive new equipment not present on the old 2000 Series, including information and control systems and inter-car connecting doors, Hitachi reduced the weight of the new rolling stock by developing a hybrid structure that uses a combination of single- and double-skin sections in place of the double-skin structure used in the A-train rolling stock.

Bogies

The bogies have a two-axle configuration with running wheels and horizontal wheels (guide and safety wheels).

For carbody support, in place of the swing bolster configuration used on the previous 500 to 2000 Series, the 10000 Series bogies have been made lighter by using a bolsterless configuration with the carbody supported directly by pneumatic springs mounted on top of the bogie frame.

Whereas the previous foundation brake had one pneumatic-hydraulic converter for each caliper, the 10000 Series has reduced the component count by using a series connection with each pneumatic-hydraulic converter operating two calipers.

Maintenance work has also been reduced by fitting wireless pressure sensors on the running tires to provide continuous display of tire pressure on autonomous decentralized train integrated system (ATI) screens.

ROLLING STOCK DESIGN

Exterior Design

The basic exterior design has a fresh feel with an unpainted hairline finish that takes advantage of the

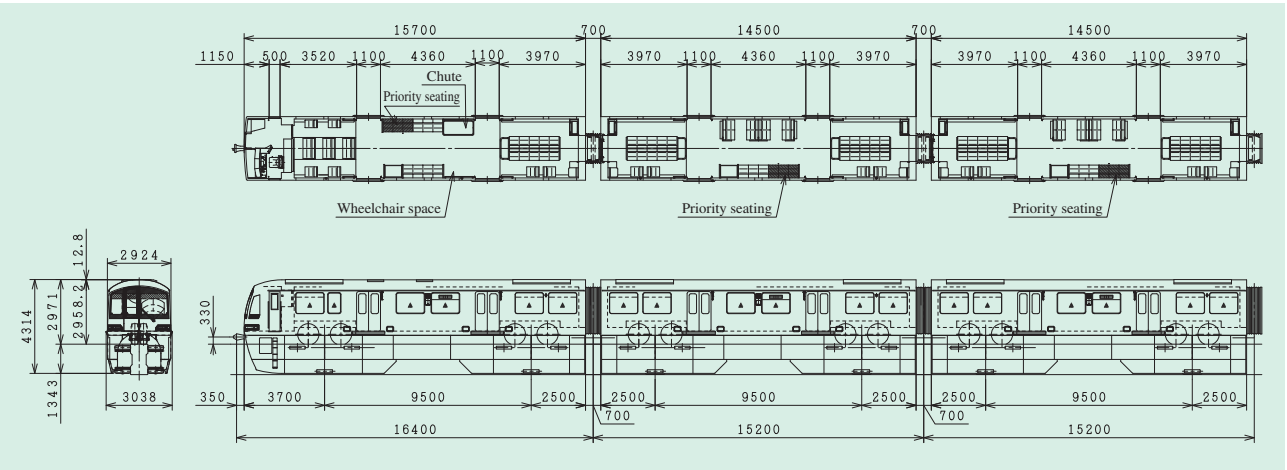


Fig. 1—Rolling Stock Layout and Dimensions (mm).
The monorail has a fixed six-cars-per-train configuration (Tc1-M1-M2-M3-M4-Tc2), with barrier-free access to the passenger compartment provided in the form of wheelchair space on the leading car and priority seating in all cars.

Fig. 2—TMK10000 Series Monorail Rolling Stock.
The design uses a color film representing sky, sea, and parkland on the side of the cars to keep in harmony with the surroundings, with a bold black design for the front.

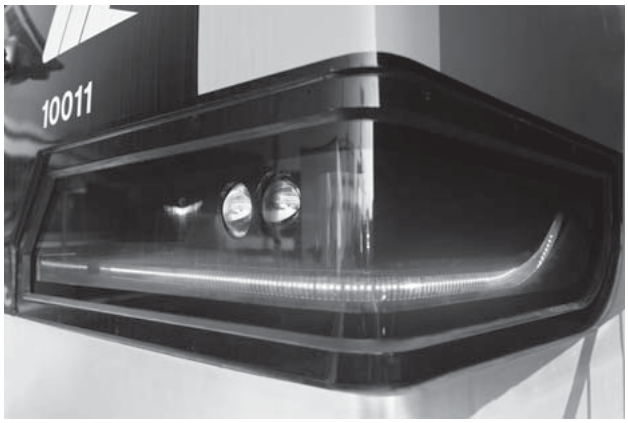
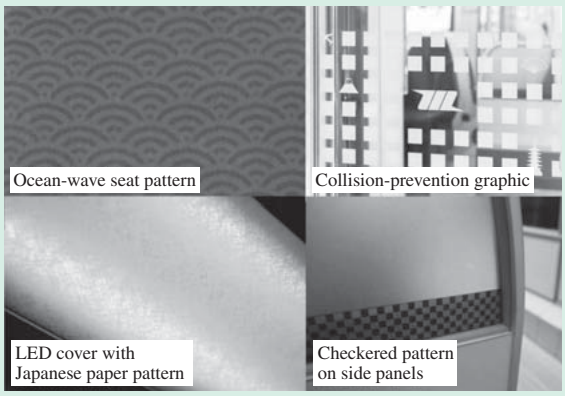


Fig. 3—Sidelights.
The sidelights are sky blue, the representative color of the Tokyo Monorail.



LED: light-emitting diode

Fig. 4—Various Interior Designs.
Since the monorail is also used by visitors from overseas, the interior design is based on Japanese motifs throughout.

texture of aluminum, while the sides of the cars are coated in a film that combines green with a shading of blue into sky blue to represent the sky, sea, and parkland character of the surrounding area (see Fig. 2).

The fronts of the cars have a design that embodies the advanced features of the new rolling stock, presenting a bold impression with black as the keynote color, and incorporating sidelights, which is a first for a monorail car (see Figs. 2 and 3).

The car design is also intended to be appreciated from a variety of angles, with the Tokyo Monorail logo appearing on the car roofs, which can be seen from elevated sites such as the tops of buildings.

Interior Design

Since the monorail is also used by visitors from overseas, the interior design presents a theme of Japanese hospitality throughout, with the following four key features (see Fig. 4).

(1) Ocean-wave pattern on seats

(2) Collision-prevention graphics on inter-car connecting doors with distinctively Japanese icons, such as Mount Fuji and a five-story pagoda

(3) Design of interior light-emitting diode (LED) lights covered with a Japanese paper pattern

(4) Checkered pattern on side panels by raised-floor seats

Additionally, glass is used for the passenger seat side panels, luggage racks, and inter-car connecting doors to create a functional interior with a light and spacious feel.

SAFETY IMPROVEMENTS

Indicator Lights for Opening and Closing Doors

Lights are installed above the doors to indicate when they are opening or closing. While typically the only function of these indicators, which are also used on other trains and monorails, has been to flash red to warn when the door is opening or closing, Hitachi has developed two-color indicators (red and blue) with three display patterns: continuously on, flashing, and a pattern of moving lights in which all elements turn on and then progressively turn off from the center to the two edges. These three display patterns present passengers with a series of escalating warnings, as follows (see Fig. 5).

(1) As the monorail approaches a station, the indicator above the door that will open displays the moving light pattern in blue.

Fig. 5—Indicator Lights for Opening and Closing Doors.
The indicator uses two-color LEDs (red and blue) to display a repeating pattern of moving lights in which elements progressively turn off in the directions shown by the arrows.

Fig. 6—Side Destination Display and Detail of Service Type Display.
Contrast enhancement is used around the edges of the "空港快速" and "Haneda Express" text.

(2) On arriving at the station, the indicator turns red above the door that will open.
(3) When the doors open or close, the indicator flashes red.

Sidelights

As noted above, the safety of the new rolling stock has been improved by fitting sidelights (of the sort that are mandatory on motor vehicles) to a monorail for the first time so that they can be used, both when running and stopping, to indicate the width of the cars to anyone in the vicinity (see Fig. 3)

Side Destination Display

A full-color display is used to allow a color-coded background to indicate the service type and the use of white for the text, since white typically provides the best visibility when overlaid on the service type color. The display is also "barrier-free" in that the background color is dimmed around the edges of the text to provide contrast and make the sign easier to read for people with color-impaired vision (see Fig. 6).

Longer Battery Operation

While the normal practice on train and monorail rolling stock is to supply high-voltage power from the catenary to a static inverter (SIV), which in turn supplies low-voltage power to the various other devices, on-board batteries can be used to operate equipment during an emergency (when power from the catenary is lost) (see Fig. 7). However, because non-essential equipment continues to operate during

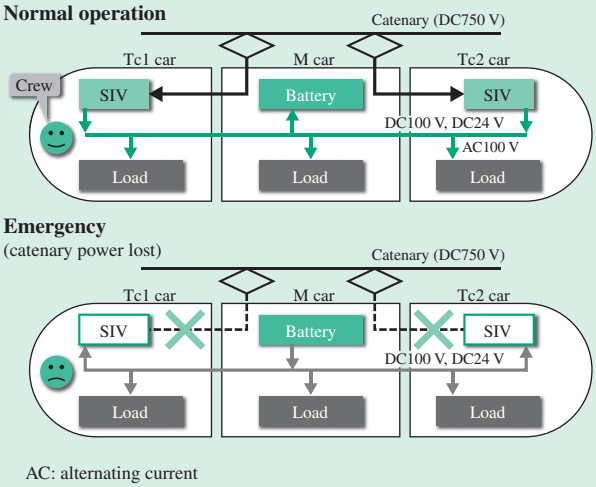


Fig. 7—Power Supply Configuration in Existing Rolling Stock during Normal and Emergency Situations.
The arrows indicate the flow of power.

an emergency, the new rolling stock is fitted with a switch that can turn off all of these loads after a switchover to battery power occurs, thereby doubling the battery operating life compared to that of existing rolling stock, from 30 to 60 minutes.

Another problem when operating on battery power is that, after all battery power has been used, the power supply fails to restart even when catenary power is restored, with the result that the rolling stock is unable to proceed under its own power. To prevent this, the circuitry in the new rolling stock is designed to turn off the battery power automatically after 60 minutes so that enough power will remain to restore the power supply when the catenary power comes back on.

CONCLUSIONS

This article has described the development concept behind the 10000 Series rolling stock for the Tokyo Monorail and the results of development.

In the future, Hitachi intends to continue striving to develop rolling stock that incorporates more added value by utilizing the latest technologies and carefully considering the design.

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