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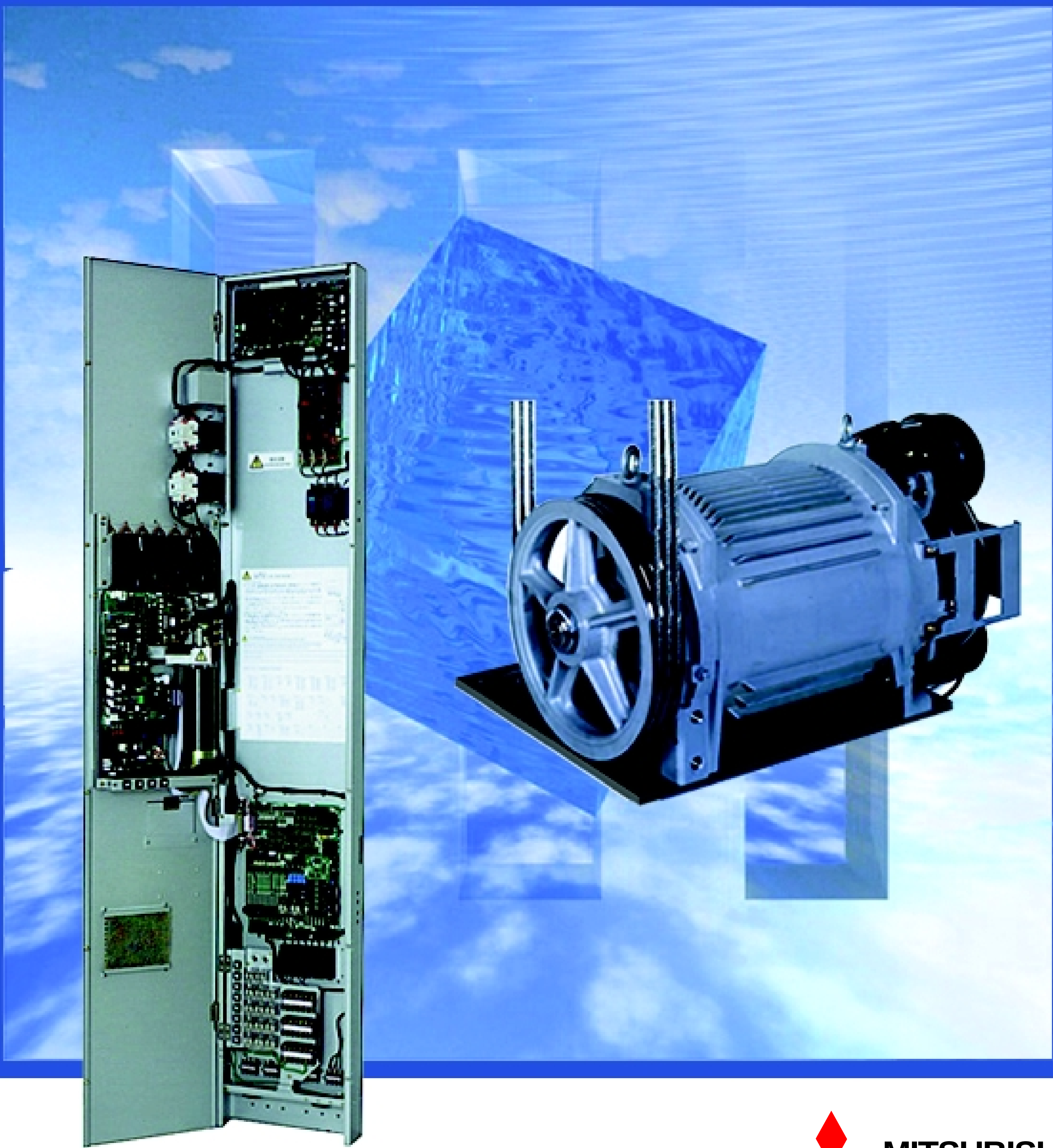
MITSUBISHI ELECTRIC ADVANCE

Elevator Edition



MITSUBISHI ELECTRIC

A Quarterly Survey of New Products, Systems, and Technology
●Vol. 88/Dec. 1999 Mitsubishi Electric **ADVANCE**

Elevator Edition

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Technical Reports

New Products

Mitsubishi Electric Overseas Network

Our cover for this issue features the new traction machine for the latest generation of our GPQ series elevators, using a new syncrhonous permanent magnet motor, and the control panel for this series, 80% smaller in volume than preceding comparable types.

Editorial Inquiries
Masakazu Okuyama
Corporate Total Productivity Management & Environmental Programs
Mitsubishi Electric Corporation
2-2-3 Marunouchi
Chiyoda-ku, Tokyo 100-8310, Japan
Fax 03-3218-2465

Product Inquiries
Yasuhiko Kase
Global Strategic Planning Dept.
Corporate Marketing Group
Mitsubishi Electric Corporation
2-2-3 Marunouchi
Chiyoda-ku, Tokyo 100-8310, Japan
Fax 03-3218-3455

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Overview

Introducing the Special Edition on Elevators

*by Sueo Okabe**

The last century has seen vertical transportation extend human living and working space to high-rise buildings and areas below ground. Few would deny the critical role it plays in supporting urban life as we know it, with its high population densities and dependence upon sophisticated functions.

Inverter technology and elevator group control using artificial intelligence are among the important innovations designed to improve convenience and comfort. Elevators are also being designed to add a visual accent to the buildings within which they are used.

As we enter the 21st century, we can expect to see elevators that are friendlier to the user and to the environment, with measures adopted specifically to meet the needs of the elderly and and the physically challenged. The widespread adoption of universal design will make using elevators a simple pleasure for everyone, and environmental concerns will be addressed by further reducing energy requirements and increasing the amount of materials that can be recycled.

The corporation's introduction of the latest technical innovations has made Mitsubishi Electric a world leader in low energy consumption. Our ongoing commitment to higher efficiency will result in less materials being used in our elevators, and more of those used will be recyclable. By offering a comprehensive selection of modernization options, we also expect to satisfy a large and growing demand for modernization.

Finally, the corporation will continue to develop and adopt the most advanced technologies, creating products that will appeal to our customers while meeting the needs of society. We thank all our customers for their support and encouragement in this continuing effort.❑

Sueo Okabe is the Manager of Inazawa Works.

Current Trends and Future Directions in Elevator Technology

*by Shigeru Abe**

Market Trends

Japan's economy has been slow and the elevator market sluggish since the collapse of the speculative bubble, but signs of an economic rebound are visible and encouraging. This slowdown has hurt elevator sales. The Asian economic crisis ended a highly visible construction boom in major southeast Asian cities, leading to the cancellation of some building projects and delays in others. China, one of the largest markets for elevators, has seen funds for building construction dry up, although not so severely as in southeast Asia. Full recovery is not generally expected before the beginning of the new century, but high-rise building construction and other redevelopment projects in Shanghai's Pudon district promise to support the market in the long term. Mitsubishi Electric has delivered high-speed elevators to the high-rise Jin Mao building and expects to receive further contracts as the Shanghai economy picks up.

Trends in Standards and Regulation

Standards in the European Union are undergoing change. The EU has revised EN81, a unified set of elevator safety regulations for the region.The European Lift Directive 96/16/EC, which has been fully ratified since July 1999, set the obligatory rules for building and operating elevators in the European Union. The US based ANSI and ASME are also revising their elevator standards. The ISO is working actively toward a single set of elevator standards, but the process is expected to take considerable time.

Technical Trends

ELIMINATING THE MACHINE ROOM. Traction-type elevators that hoist the car with a wire rope require a machine room at the top of the building. This need affects the building shape and constrains locations where elevators can be installed. Hydraulic elevators offer more flexibility regarding equipment location, but limit the maximum travel and consume more energy. The environmental impact of the mineral oil hydraulic fluid may also be an issue. Mitsubishi Electric has focused on developing machine-roomless elevators for the European and Japanese markets. The Mitsubishi GPQ Series fits the traction equipment and control electronics entirely within the elevator shaft, eliminating the need for an external machine room.

PERMANENT MAGNET TRACTION MOTOR. In advance of other manufacturers, Mitsubishi Electric has introduced a new type of gearless traction machine with a permanent magnet (PM) for high-speed elevators. This unique application of a PM motor effects several improvements including higher efficiency, greater comfort, and miniaturization.

HIGHER SPEEDS, LARGER LOADS. Passenger transportation efficiency is a central issue as buildings grow larger and taller. The group control systems that manage multiple elevator implement new scheduling algorithms that significantly boost transport efficiency. In a market climate that increasingly emphasizes capacity, double-deck elevator cars capable of serving two floors at a time have appeared. Mitsubishi Electric has developed high-capacity power modules and motors for this application and is already delivering them to customers worldwide.

Toward Harmonized Regulation

Elevator regulations differ from nation to nation. An elevator manufacturer serving the global market must satisfy three key sets of standards: EN in Europe, ANSI in the United States, and JIS and national building code in Japan. Other countries add their own requirements, but most generally follow European standards. While the EU has established a single standard for its member countries, Canada and the US have merged their regulations. China generally follows the EU standards while retaining some elements of the British code. Manufacturers are continuing to work through the ISO toward worldwide standards.

Modernization

More than five million elevators are estimated

**Dr. Shigeru Abe is with Inazawa Works.*

to be in use worldwide. The life of an elevator depends on its maintenance and operating environment. Most are renewed after 20 to 30 years. With such a large base of installed elevators needing renewal, this market is a significant one.

Older elevators suffer from higher power consumption, longer passenger waiting times, lower transportation efficiency and lower riding comfort than newer models. These factors will necessarily expand the volume of modernization projects.

Environmental Considerations

Considering environmental issues is imperative in the design of modern elevator products. Three areas stand out:

ENERGY SAVINGS. Fig. 1 shows energy savings achieved in successive Mitsubishi elevator products. Continued energy savings are needed to conserve fossil fuels and minimize man's contribution to global warming.

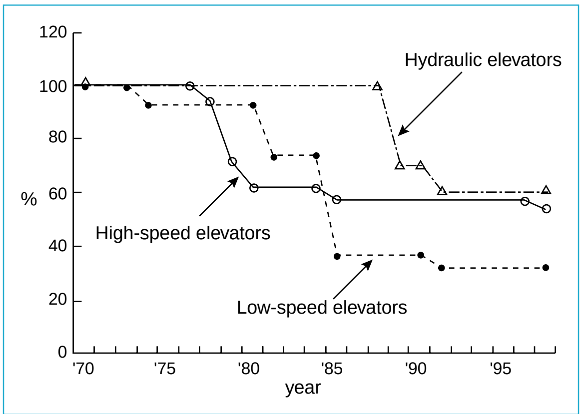


Fig. 1 Energy savings in successive elevator products.

RESOURCE CONSERVATION. Resources can be saved by designing products to be lighter, by designing them to consume less energy in manufacturing, by simplifying product packaging and by recycling packaging materials.

WASTE MANAGEMENT. Processes are designed to minimize waste products. Wastes are recycled wherever possible.

Various plans for larger, higher buildings have been proposed. Mitsubishi Electric has delivered the world's fastest elevators-with a top speed of 12.5m/sec (750m/min)-to the Yokohama Landmark Tower and will continue to push the envelope. While these elevators may be the fastest, new technologies allowing multiple cars to share a single shaft or to operate entirely without hoist cables will surely draw attention. ❑

New Model GPS-III and GPM-III Series Elevators

*by Hiroshi Ando and Hiroyuki Ikejima**

The article introduces features and new technologies in Mitsubishi Electric's new-model GPS-III and GPM-III series elevators designed for improved efficiency, reliability and comfort. See Fig. 1.

Traction Motor

Induction motors are used. A traction motor with a 10% smaller sheave diameter saves machine-room space in elevators with load capacity under 600kg and speed and 60m/min, while redesigned gearing and a smaller traction motor save space in 120~150m/min elevators with 750~1,050kg capacities.

Shaft Dimensions

Thinner car walls and doors have been developed that reduce the shaft size of these made-to-order elevators. Reinforcing members in the car walls have been repositioned and optimized through structural analysis to reduce wall thickness by 20%. New stamping and joining technologies reduce the number of door components while trimming door thickness by 40%.

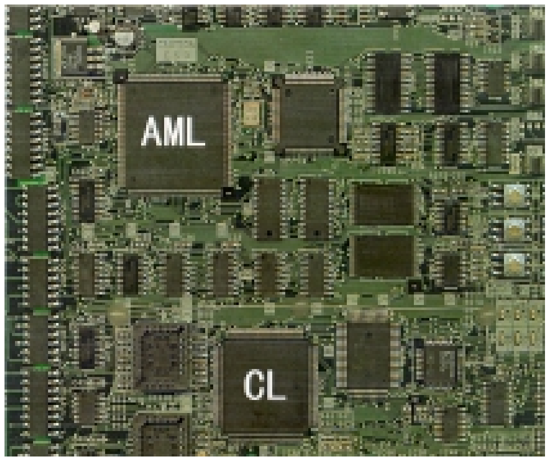


Fig. 2 The control board showing the AML central processor unit.

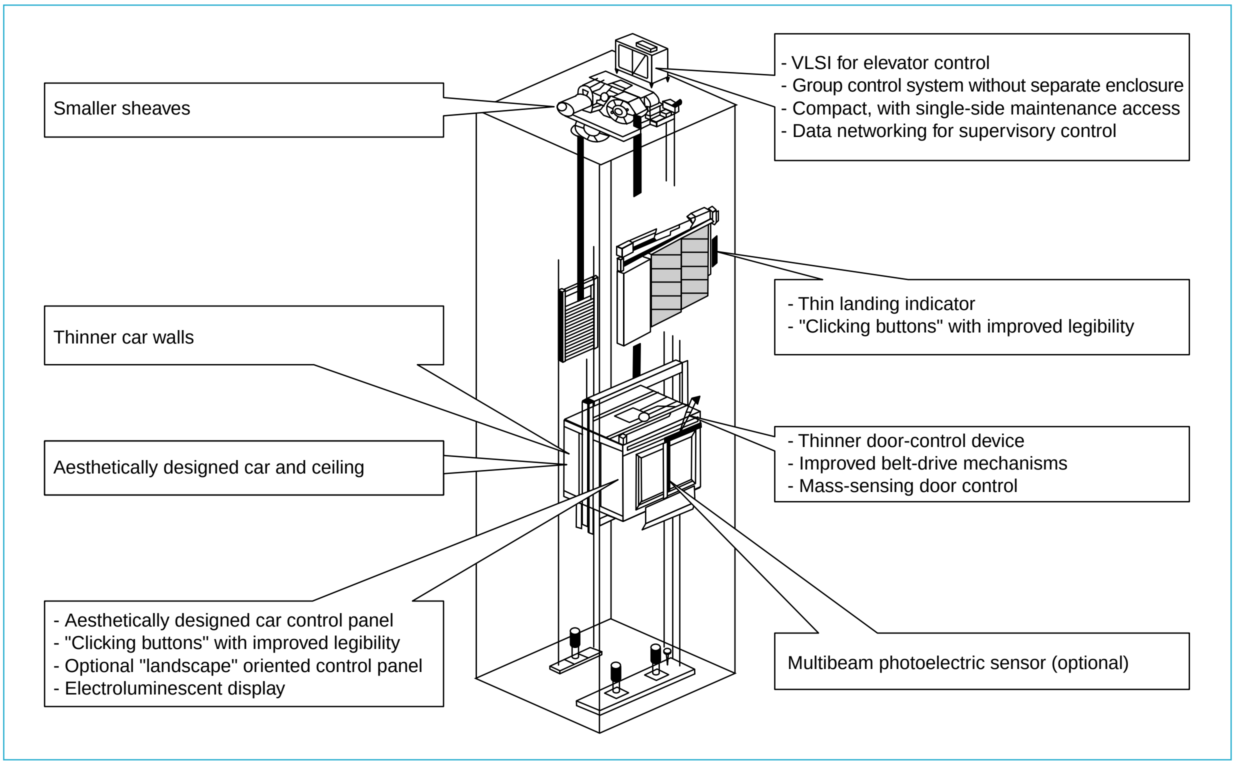


Fig. 1 Feature List.

**Hiroshi Ando and Hiroyuki Ikejima are with the Inazawa Works.*

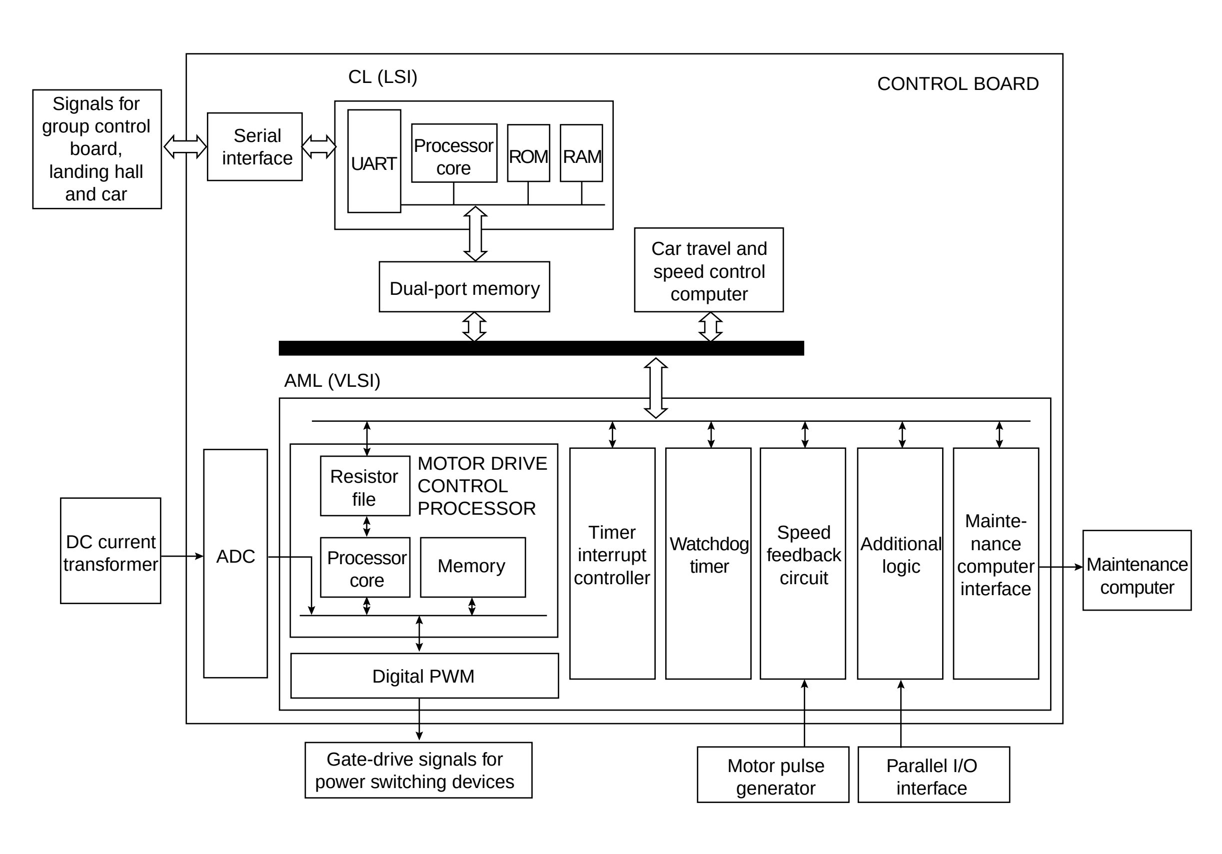


Fig. 3 A block diagram of the control system.

Drive and Control Circuitry Implemented in VLSI

Integrating major elevator control circuitry in a single VLSI called Associated Management Logic (AML) boosts performance while reducing the control electronics to the small board shown in Fig. 2. The AML chip implements a traction motor drive control processor and operation control logic in 300,000 gates. The device generates control signals for the inverter and the transistor converter. Fig. 3 shows a block diagram of the control system and AML architecture. The AML chip can compute motor current control commands in one fifth the time of previous processors, which permits smoother, more precise and more comfortable car operation. High-speed elevators feature a smaller and more reliable inverter due to a new short-circuit protection function that no longer requires a voltage feedback circuit to correct its time characteristics.

Compact Electronics

The enclosure for the control system electronics is located in the machine room. Its volume has been reduced by 30 to 50%. The control panel for high-speed elevators has been redesigned to permit all maintenance access from one side of the enclosure. This single-side access simplifies machine room equipment layout and reduces room size. Group control functions for 45~105m/min elevators are now integrated in the control panel, eliminating the separate enclosure previously required.

More compact dimensions were achieved by introducing low-impedance insulated copper busbars that can be closely spaced. Two kinds of insulated busbars are used. One type is insulated by a sandwich of PET film, the other has a PPS coating formed by injection. Thermal analysis has made it possible to redesign the inverter heat sinks for reduced volume while boosting main circuit reliability.

Simpler connections to the main control board also save space. Interface boards are connected via high-speed differential-operation serial buses. All cards receive power from a bus bar in the front panel. The bus connectors also exit the front of the panels. This eliminates the need for backplane connections, boosting reliability and reducing rack size.

Improved Door Operation

Several improvements in belt-drive mechanisms now enable them to replace the mechanically linked drives previously required to operate spe-

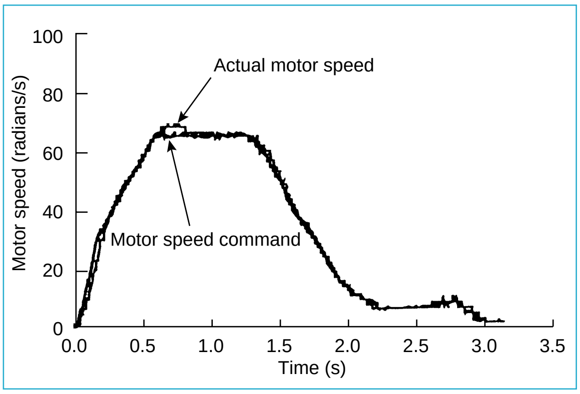
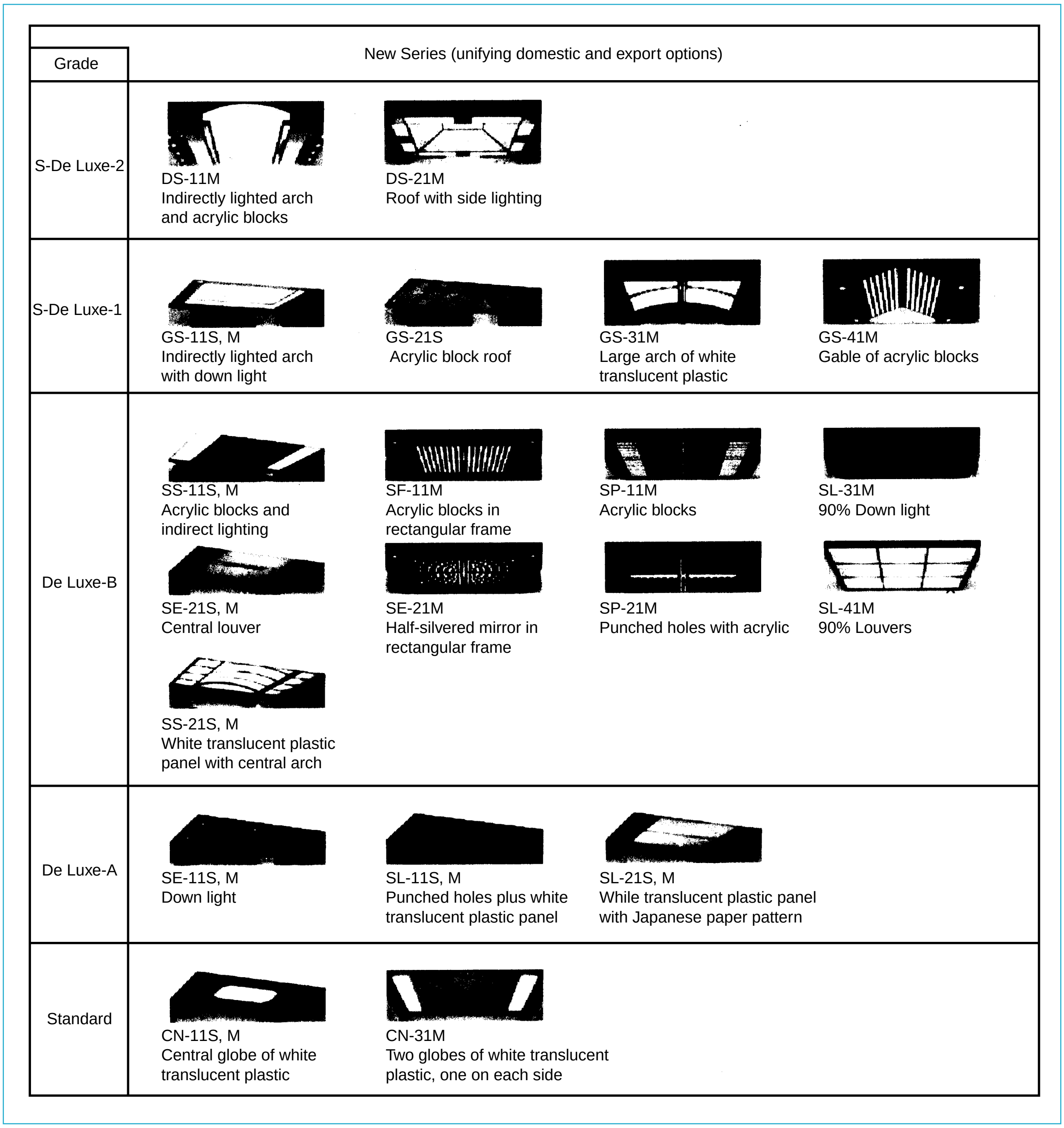


Fig. 4 Motor speed during door operation.

cialty doors incorporating glass and other heavy materials, see Fig. 4.

STRONGER MECHANISM. The belt-drive mechanism is 25% faster than previous belt systems while weighing 30% less than mechanically linked drives. Durable high-traction belts have been adopted, especially for the heavily loaded deceleration mechanism.

MASS-SENSING DOOR CONTROL. A control system that automatically adjusts the motor power and speed to suit doors of various weights has been developed. A RISC-type high-performance 32-bit monolithic microprocessor provides the



Grade	New Series (unifying domestic and export options)			
S-De Luxe-2	DS-11M Indirectly lighted arch and acrylic blocks	DS-21M Roof with side lighting		
S-De Luxe-1	GS-11S, M Indirectly lighted arch with down light	GS-21S Acrylic block roof	GS-31M Large arch of white translucent plastic	GS-41M Gable of acrylic blocks
De Luxe-B	SS-11S, M Acrylic blocks and indirect lighting	SF-11M Acrylic blocks in rectangular frame	SP-11M Acrylic blocks	SL-31M 90% Down light
	SE-21S, M Central louver	SE-21M Half-silvered mirror in rectangular frame	SP-21M Punched holes with acrylic	SL-41M 90% Louvers
	SS-21S, M White translucent plastic panel with central arch			
De Luxe-A	SE-11S, M Down light	SL-11S, M Punched holes plus white translucent plastic panel	SL-21S, M While translucent plastic panel with Japanese paper pattern	
Standard	CN-11S, M Central globe of white translucent plastic	CN-31M Two globes of white translucent plastic, one on each side		

Fig. 5 Five levels of the new elevator lineup.

computing power needed to process motor torque commands for opening or closing the doors while monitoring a pulse generator to determine actual motor speed. The motor speed reveals the door mass, and the processor uses this information to adjust torque commands accordingly.

MULTIBEAM PHOTOELECTRIC SENSOR. Two photoelectric sensor systems are available to reverse closing doors if a person or object is blocking the doorway. One is a two-dimensional sensor that detects objects in the plane of the door. The other is a three-dimensional sensor that extends the detection area in the direction of the landing so that a closing door will open to admit a late-arriving passenger.

(a) CBM-B150, "landscape" oriented control panel

(b) CBM-A110, control panel

Fig. 6 Aestheticaly designed control panels

Aesthetic Design

CAR INTERIOR. New car interiors have been developed. Separate ceiling illumination choices for export and domestic markets have been folded into a new five-level product scheme that shares incandescent down lights and indirect illumination. These products, listed in Fig. 5, are designed to harmonize with modern architectural design and building interior decor.

CAR CONTROL PANEL. Fig. 6 shows the two control panel choices. An auxiliary control panel with buttons arranged in a horizontal direction is available for placement at heights of 900~1,100mm to facilitate travel by children and wheelchair users. The new elevator cars retain the LED dot-matrix display and the wave design of previous door controls. The buttons now incorporate a tactile-feedback mechanism so that they click when pressed. To improve legibility, the font size for the button labels has been increased by 1mm to 13.5mm and high-contrast colors have been used.

LANDING INDICATOR AND CALL BUTTON. The thin, 16.9mm landing indicator can be bolted directly to the wall, eliminating the labor and materials cost of a recessed box. An electroluminescent display that is bright, easy to read and displays more information than the standard indicator is also available. The electroluminescent panel was selected for flicker-free operation and a wide viewing angle.❑

Elevators Without a Machine Room: the Mitsubishi GPQ Series

*by Takenobu Honda and Eiji Ando**

Designed for residential/business complexes, Mitsubishi Electric GPQ Series elevators accommodate all traction equipment within the elevator shaft, eliminating the machine room and easing architectural constraints. The 45m/min models require an overhead of 3,150mm at the top of the shaft, comparable with hydraulic elevators and less than previous traction designs. A 60m/min model with nine-passenger capacity and five landings consumes 30% less space than a comparable hydraulic model.

Table 1 lists the basic elevator types. The elevators target the domestic Japanese market and comply with JIS regulations. Traction technology permits the elevators to handle travel distances up to 60m and as many as 25 landings compared to the 20m travel limit of hydraulic elevators.

Table 2 compares the floor space taken up by GPQ, hydraulic and previous traction models assuming a 9-passenger capacity, 60m/min speed and five landings. The GPQ series takes up 30% less floor area than hydraulic elevators and 35% less than conventional traction models, allowing more floor space for income-generating purposes.

Table 3 compares the energy consumption of the same three elevator types. Use of a permanent magnet synchronous traction motor and gearless drive reduces the power consumption of GPQ elevators to 20% less than traction elevators.

The ride comfort of GPQ series elevators is comparable to high-speed elevators thanks to a quiet and responsive traction motor and sophisticated motor control technology.

To simplify building structural design, the weight of the elevator equipment is carried through the guide rails to the pit floor, placing minimal loads on the top of the building.

The control panel is installed in the shaft, supporting flexibility in landing design. Call buttons with tactile feedback, car buttons with audible feedback and braille indications serve riders of all abilities.

Table 1 Product Types

Type	R		P	
Passengers	6	9	6 or 9	11, 13 or 15
Load (mass)	450kg	600kg	450 or 600kg	750, 900 or 1,000kg
Rated speed	45 or 60m/min	45, 60 or 90m/min	45, 60 or 90m/min	45, 60, 90 or 105m/min
Maximum car travel	60m			
Maximum landings	25			
Drive	Traction			

Table 3 Comparative Power Consumption of Mitsubishi Elevators

Elevator	GPQ	Earlier traction model
Motor capacity	3.7kW	5.5kW
Power feed capacity	4kVA	6kVA
Yearly power consumption	2,590kW.h	3,230kW.h

Table 2 Comparative Space Requirements of Mitsubishi Elevators

Elevator	GPQ "Packaged" Series	Hydraulic model	Earlier traction model
Shaft Width x depth Floor area used (5 landings)	1.55 x 2.1m $16.3m^2$	1.65 x 2.3m $19.0m^2$	1.55 x 2.1m $16.3m^2$
Machine room Width x depth Floor area used	0 0	2.4 x 1.9m $4.56m^2$	2.4 x 3.8m $9.12m^2$
Total floor area used	$16.3m^2$	$23.5m^2$	$25.4m^2$
Overhead	3,200mm	3,200mm	4,450mm

**Takenobu Honda and Eiji Ando are with the Inazawa Works.*

Layout

Fig. 1 shows a vertical section of the elevator shaft. Fig. 2 shows shaft cross sections for three elevator types. The traction machine is installed at the base of the shaft under the guide rails with a sheave at the top of the guide rails. The hoist cable also passes over pulleys at the bottom of the elevator car and the top of the counterweight. The ends of the hoist cable are fixed at the top of the guide rails, one on the side of the elevator car, the other at the side of the counterweight. With this arrangement the entire mechanical weight of the elevator is supported by the pit floor. The upward pull of the traction motor and downward load of the sheave compress the guide rails, relieving the building of these loads.

Traction Machine

Fig. 3 shows the traction machine. A disk-type brake mechanism with dual calipers is used. The brake is normally released by an internal electromagnet, although it can also released manually from the landings in emergencies.

Fig. 4 shows the configuration of the traction motor and drive system. The drive system ensures a smooth, comfortable ride by utilising a

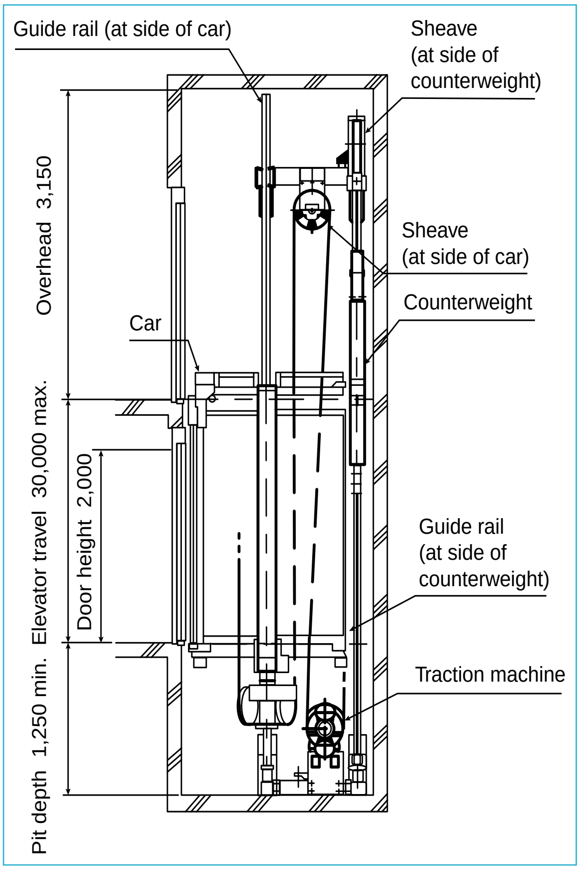


Fig. 1 Elevator shaft, vertical section (dimensions in mm).

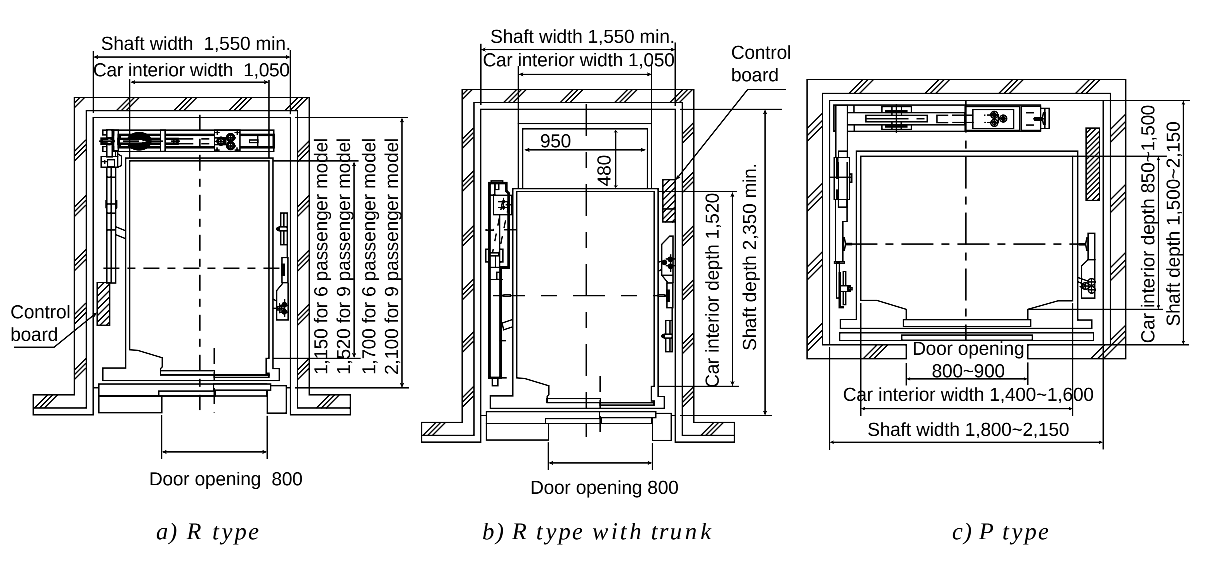


Fig. 2 Shaft cross sections (dimensions in mm).

system that precisely controls traction motor speed and torque. Encoder pulses provide feedback to the speed-control loop while armature current and magnetic polarity serve as feedback for the current control circuit.

Fig. 5 shows the speed, acceleration and armature current waveforms for upward operation with a full load at a top speed of 60m/min.

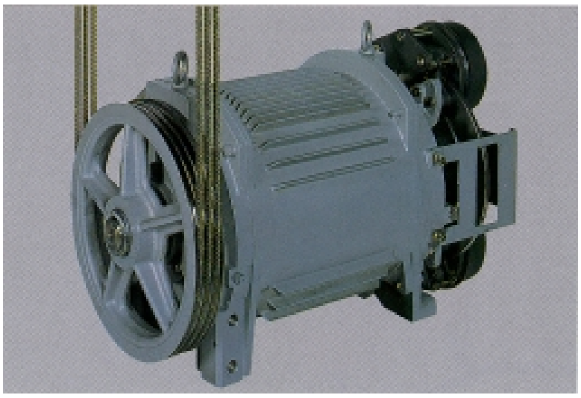


Fig. 3 Traction machine.

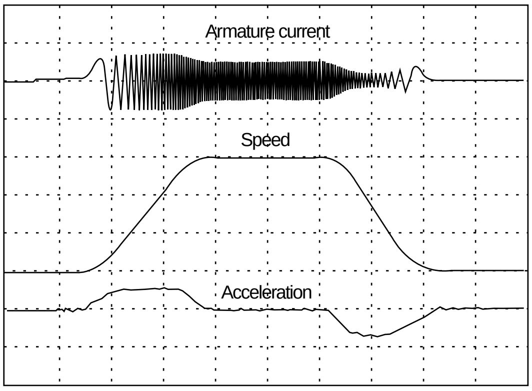


Fig. 5 Operating waveforms.

Control Board

The control panel functions are divided between

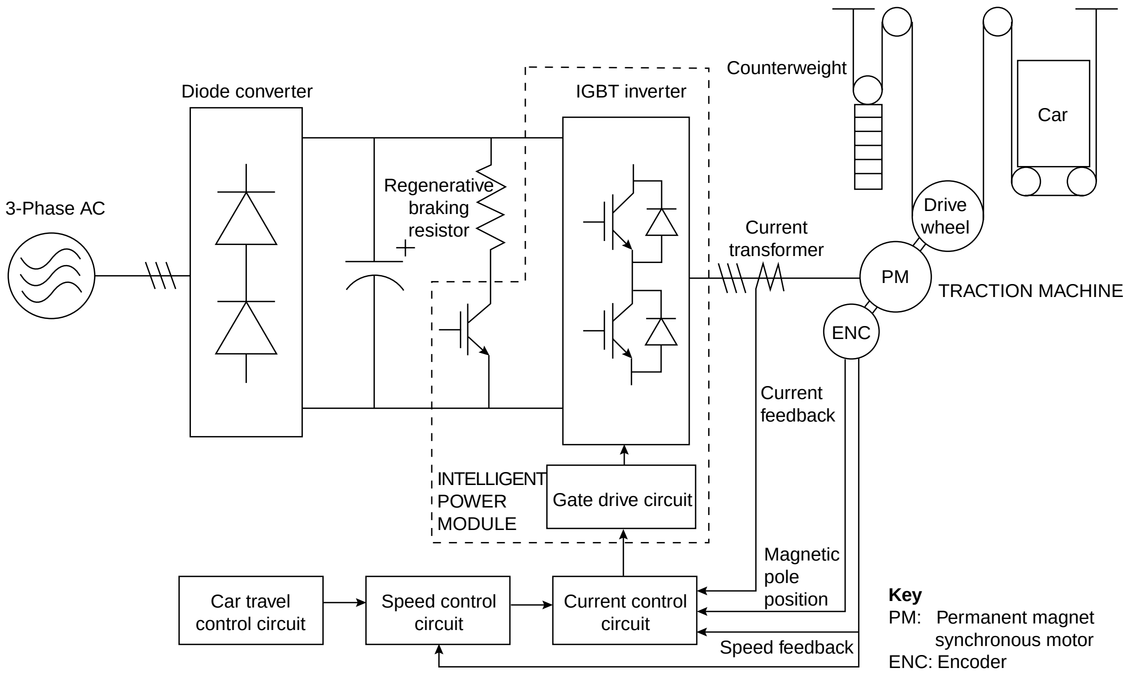


Fig. 4 Drive system.

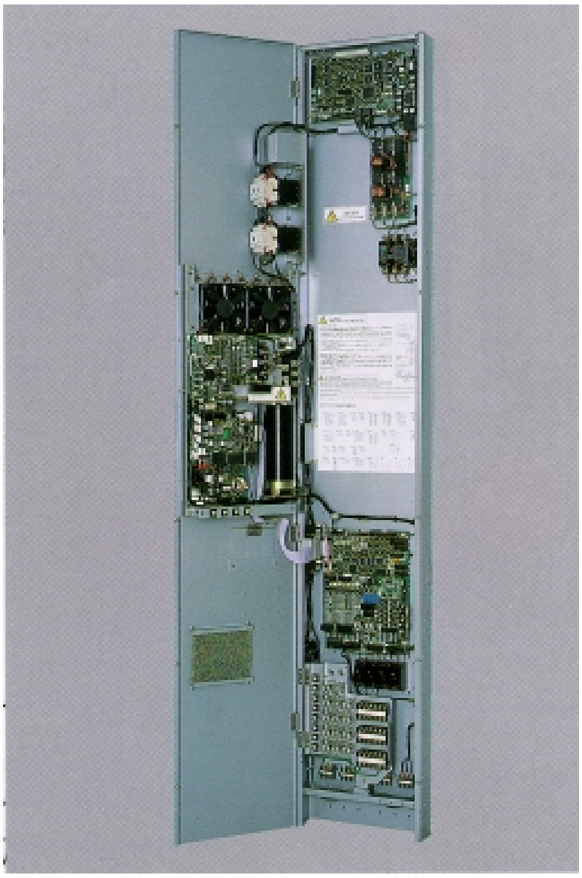


Fig. 6 Control board.

landing control units on each floor and a main equipment enclosure at the base on the shaft. Fig. 6 shows a photo of the enclosure. To fit between the shaft wall and elevator car side wall, the volume of the main unit has been reduced by 80% in a new design with an 87mm thickness and 340mm width. The entire unit can be raised or lowered to allow maintenance as required.

The size of the control panel was reduced dramatically by replacing the power supply circuit's line-frequency transformer with a switching transformer and using a low-voltage DC supply throughout. A voltage-multiplying chopper circuit provides high-voltage power for the brake exciter circuit and door drive inverter. The thickness of the traction motor's inverter unit has been halved by using a specially developed heat-pipe cooling unit just 22mm thick. Wiring between the inverter and power supply unit is as short and direct as possible.

Fig. 7 Car interior.

The aesthetic design of the elevators follows that of GPS series elevators, with enhancements to the car interior, shown in Fig. 7. The ceiling has a translucent arch with soft backlighting and slit-shaped accents on either side.

Mitsubishi GPQ series elevators combine the space savings of hydraulic elevators with power efficiency even better than previous traction models, making them desirable in buildings where floor space is at a premium. ❑

High-Speed High-Capacity Elevators for Ultrahigh-Rise Buildings

by Hiroshi Araki and Yasushi Chadani

Recent years have seen a resurgence of interest in extremely high-rise buildings. These buildings place extraordinary demands on elevator systems-their primary mode of transportation. Mitsubishi Electric has developed new technologies extending the speed of its elevators to an industry-leading 540m/min with a load capacity of 4,000kg. Permanent-magnet traction motors, inverters, an improved safety gear device, oil buffer and other new technologies were developed.

Traction Motor

Squirrel-cage AC induction motors have been used to provide variable-speed capabilities for gearless, direct-coupled traction applications for more than a decade, replacing the DC motors previously used. Applications of rare-earth permanent magnets to electric motors have expanded dramatically as new formulations with increased flux density and coercive force have been developed and become available in production quantities. Mitsubishi Electric has developed the industry's first permanent-magnet based high-capacity traction motors for over 120m/min and over 300m/min elevator applications, replacing the squirrel-cage induction motors previously used. Fig. 1 shows the motor and its control system. The motor is more efficient since no excitation current is required, while lower levels of harmonics mean that operation is quieter. Here we will introduce the features of permanent magnet traction motors for speeds exceeding 300m/min.

Rare-earth magnets are manufactured in samarium-cobalt, neodymium and praseodymium formulations, each with different properties. Neodymium was chosen for this application for its high flux density and high coercive force that yield a high energy value, the BH product. In addition, neodymium has excellent temperature characteristics. Table 1 compares characteristics of the three types of rare-earth permanent magnets.

Smaller traction motors are desirable since they reduce the size and cost of the machine room where the motors are housed. Smaller motor size is generally achieved by use of a multi-pole design that reduces the core diameter and coil end length. Size reductions in induction motors are limited by the drop in power factor associated with multi-pole designs. Permanent magnet motors operate efficiently re-

Table 1 Comparison of Rare-Earth Magnets

Rare-earth	SmCo	Nd	Pr
Maximum accumulated energy	High	Very high	High
Temperature characteristics	Excellent	Excellent	Fair

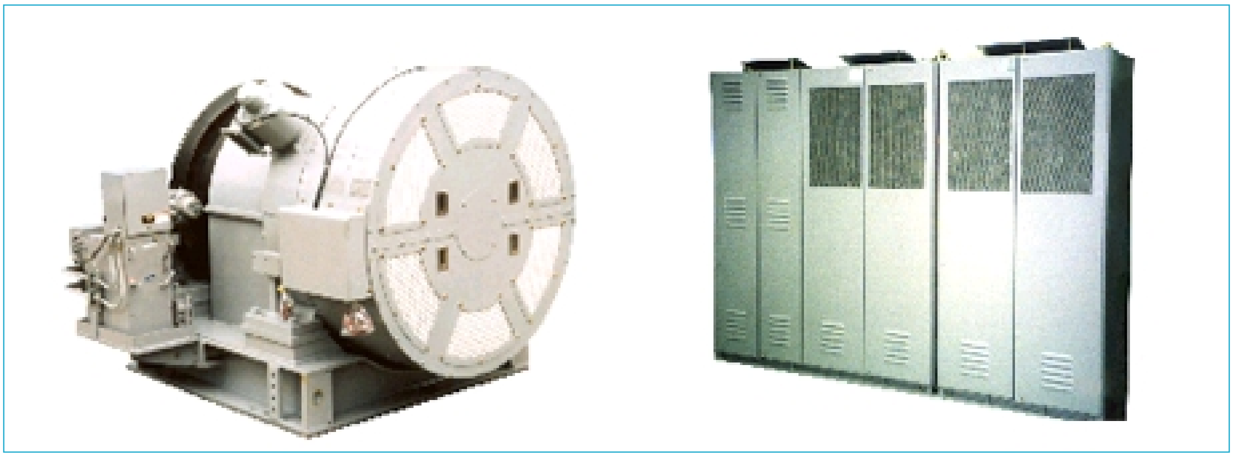


Fig. 1 The traction motor and its control system.

Hiroshi Araki and Yasushi Chadani are with Inazawa Works.

gardless of the number of poles, and hence are appropriate for compact multi-pole designs, especially now that solid-state inverters can operate at the higher frequencies required by multi-pole designs.

Since an increase in pole number means more components and more complicated and time-consuming manufacturing procedures, Mitsubishi Electric selected the minimum pole number satisfying miniaturization requirements.

Hydraulic Brake Unit

A hydraulic disk brake release unit was developed to handle the high torques involved, and two of these brake units were used. The equipment layout is more flexible due to the compact dimensions and fewer design constraints of the new equipment.

Controller

Fig. 2 illustrates the components of the power control system. The system consists of a power supply panel fitted with circuit breakers, an auxiliary panel with built-in reactors for the power supply and output circuits, a control panel housing the power converter and control circuitry and an inverter panel.

Heat-Pipe-Cooled Power Electronics

The weight of the hoisting ropes and electrical cables is larger in higher buildings, adding tremendous inertia to the passenger or cargo load. The traction motor must overcome this inertia to accelerate or decelerate the car, and the motor must sustain large currents to do so. The converter and inverter driving the motor employ six 600A-rated insulated-gate bipolar transistor (IGBT) modules connected in parallel. Heat pipes are used to cool the parallel-connected modules, preventing temperature differences that would result in unbalanced current flows. This better cooling permits denser component mounting-the controller can deliver double the output of previous equipment while occupying less floor space.

Control Circuitry

A high-performance DSP controls the inverter and converter. Control of permanent magnet motors is simpler than that of squirrel cage induction motors and efficiency is higher because there is neither the power consumption of the excitation coils nor the delays in energizing them. A more exacting requirement is that the rotor position must be detected precisely. This is accomplished by a cost-effective encoder that combines two types of encoding systems: an absolute encoder with markings at 45 degree intervals, and an incremental encoder that provides two phase signals and delivers a zero-signal output once per revolution.

Rotor Position Compensation

Errors in the rotor position detector output reduce motor performance and efficiency and give passengers a rougher ride. Errors in the abso-

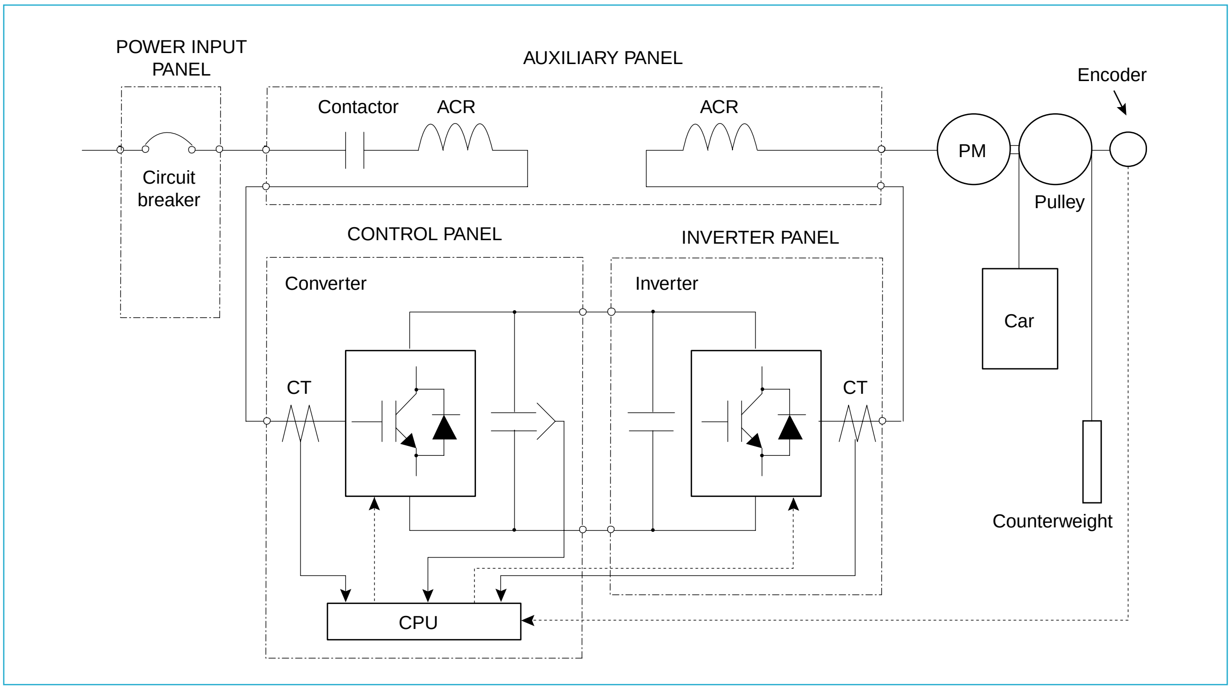


Fig. 2 Configuration of the control system.

lute encoder arise from variations in equipment mechanical alignment during assembly. Also the electrical angle signal used in the control system can differ from actual rotor angle, and this error increases with the number of poles in the motor. Elevator operation data was monitored, major error components identified and compensation implemented to overcome these effects.

Elevator Test Apparatus

The performance of motors and control programs for this high-speed, high-load application was tested by an apparatus consisting of a load motor and flywheel connected through a torque meter to the motor under test. The test simulates normal elevator operation, with the controller supplying voltage and current in accordance with actual elevator speed instructions. The load motor creates torques corresponding to the load of the elevator car and inertia of hoisting ropes and other components. This arrangement permits tests to be conducted under conditions nearly identical to actual elevator operation. Fig. 3 shows operation waveforms of a traction motor for a 540m/min elevator measured by this apparatus.

Safety Equipment

Fig. 4 illustrates the elevator safety equipment. The overspeed governor is located in the machine room and detects the elevator speed. If for any reason the elevator exceeds permissible operating speeds, an overspeed governor activates the safety gear device located under the elevator car. This device has brake shoes that stop the car by clamping onto a guide rail that runs the length of the elevator shaft. Oil buffers installed at the bottom of the shaft below the car and counterweight will smoothly decelerate the car to a stop should it ever travel beyond its lower position limit.

Safety equipment must operate correctly to serve its intended function. Standards organizations of Europe, the US and Japan (ENI, ANSI and JIS, respectively) set performance standards for elevator safety equipment.

A DUPLEX SAFETY GEAR DEVICE FOR HEAVY LOADS. An elevator car twice the height of a conventional car can increase the transport capacity of an elevator shaft. The added weight of a double-decker car, its passengers, counterweight, and the long hoisting ropes in high-rise buildings has the effect of increasing the moving mass of the system so that the safety gear device must provide more powerful braking action.

Mitsubishi Electric has developed a duplex safety gear device that meets the needs of an ultrahigh-rise 540m/min elevator with a double-decker car with braking power 50% higher than the company's previous safety gear device. Stopping power was increased 50% over a previous

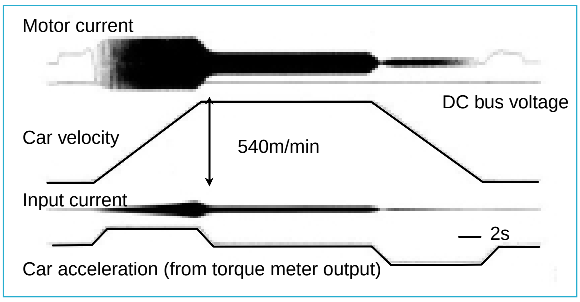


Fig.3 Waveforms during elevator operation at 540m/min.

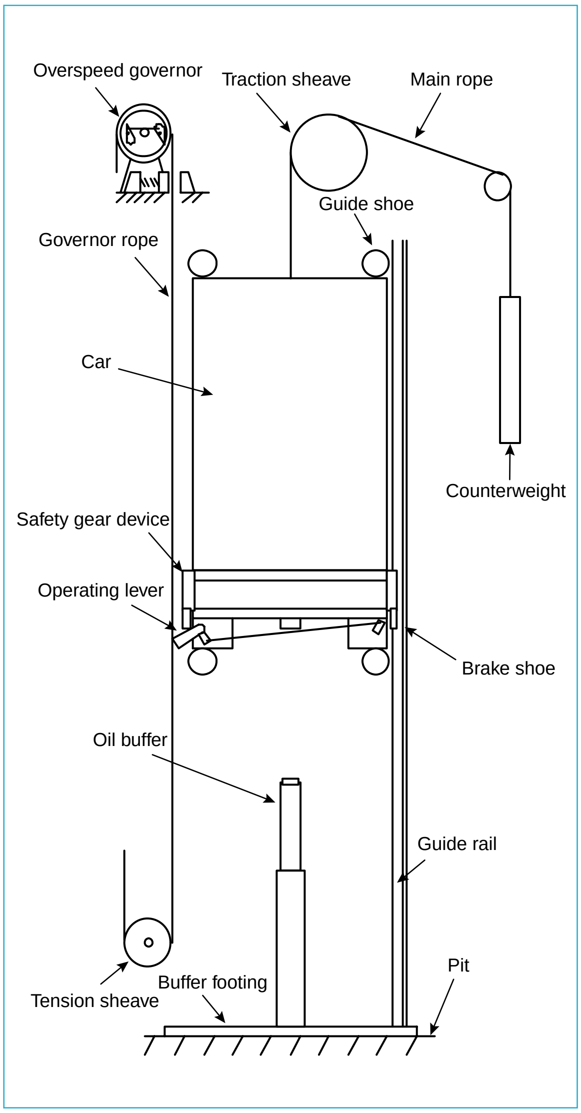


Fig. 4 Safety device components.

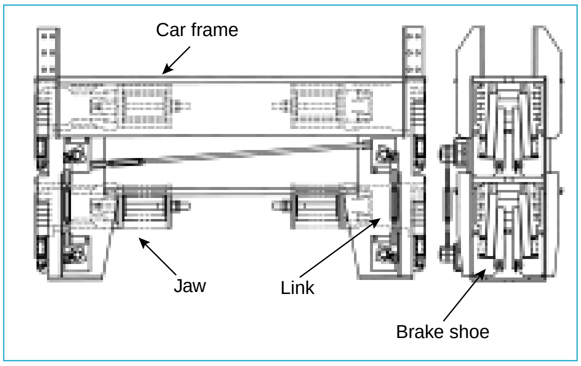


Fig. 5 Duplex safety gear device.

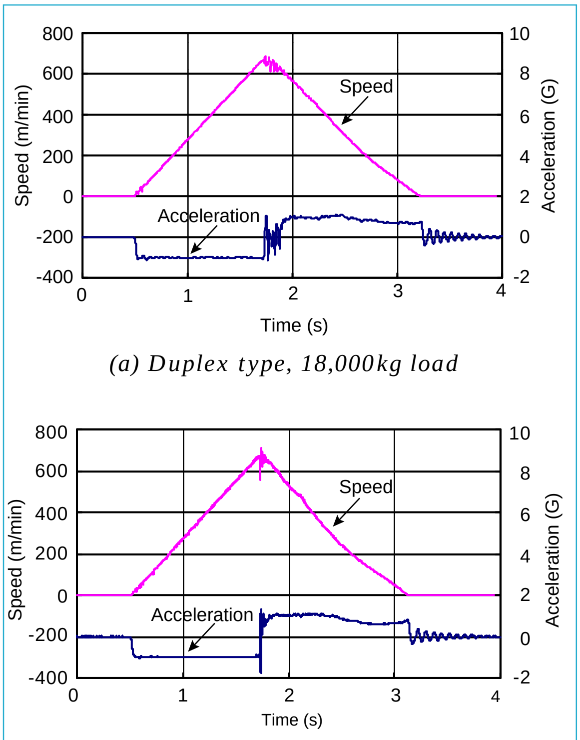
Table 2 Specifications of the Safety Gear Device

Capacity	4,000kg
Travel	350m
Maximum operating speed	675m/min
Maximum mass	176.5kN
Stopping distance	6.4~18.4m

system by using two brake mechanisms in tandem. Fig. 5 shows a diagram of this arrangement. Table 2 lists its specifications. This solution consumes less area under the elevator car than a single safety gear. A link between the upper and lower brake mechanisms ensures that both brakes operate simultaneously. A spring drives the jaw, clamping the shoes against the elevator guide rail, which provides friction to stop the car.

The duplex safety gear required testing because, while the braking behavior of shoes on virgin rail is understood, the second shoes will be gripping the rail after its surface characteristics have been altered by the braking action of the first jaw.

TESTING OF THE SAFETY GEAR DEVICE. The device was tested according to standards and procedures prescribed by the standards of the Japan Elevator Association. The curves in Fig. 6a show elevator car velocity and acceleration as a function of time while the safety gear is used to halt a load of 18,000kg traveling at about 675m/min–25% over the rated maximum speed of 540m/min. The brake achieved a full stop in about 9m, well within the required stopping distance. Fig. 6b shows similar curves when a single safety gear was used to stop a single-compartment elevator car with a 9,000kg load traveling at 540m/min. The close match indicates that the duplex mechanism provides close to double the stopping power of a single mechanism.



(a) Duplex type, 18,000kg load

(b) Single type, 9,000kg load

Fig. 6 Results of safety gear tests at 675m/min.

Advances in rare-earth magnet formulations are responsible for a new generation of compact and powerful traction motors. Mitsubishi Electric has harnessed these capabilities to increase the speed and load capacity of elevators serving ultrahigh-rise buildings, while taking steps to ensure the safety of the system under these more demanding operating conditions. ❑

A Modernising Control System for High-Speed DC Elevators

*by Toru Tanahashi and Masami Kawamura**

Mitsubishi Electric has developed a new control system for high-speed gearless DC elevators with improved operating characteristics. The system will soon enter commercial production aimed at modernizing old elevators.

The new control system's chopper circuit uses inverter technology borrowed from inverter-controlled high-speed elevators to achieve higher efficiency than thyristor Leonard systems with increased rider comfort and reduced noise. Applicable elevators will be those with speeds of 120 ~240m/min and capacities below 1,600kg. The needs of a broader range of elevators will be addressed later. This article introduces the new control system and its chopper circuit.

Main Circuit Configuration

Fig. 1 shows the basic configuration of the control system. The main circuit consists of a PWM converter and chopper circuit. AC power supplied to the system is stepped down by a transformer and then converted to a constant-voltage DC supply by the PWM converter. The chopper circuit converts this constant-voltage supply to variable-voltage power for the DC motor.

Based on 1,200V 600A IGBTs connected in parallel, the PWM converter circuit has a proven record in the company's inverter-controlled high-speed elevators. The converter maintains a sinewave input current waveform that dramatically reduces the harmonic current. Fig. 2 contrasts the square current waveform supplied by a thyristor Leonard circuit with the sinusoidal current waveform supplied by the PWM converter. The harmonic current distortion of the PWM converter is low enough that the building's power feed requires no special harmonic current protection.

The power factor for the PWM converter's input current is 1 during powering and –1 during regenerative braking. This high power factor can

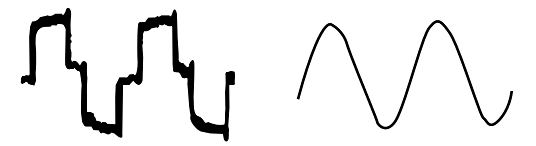


Fig. 2 Comparison of power source current waveforms.

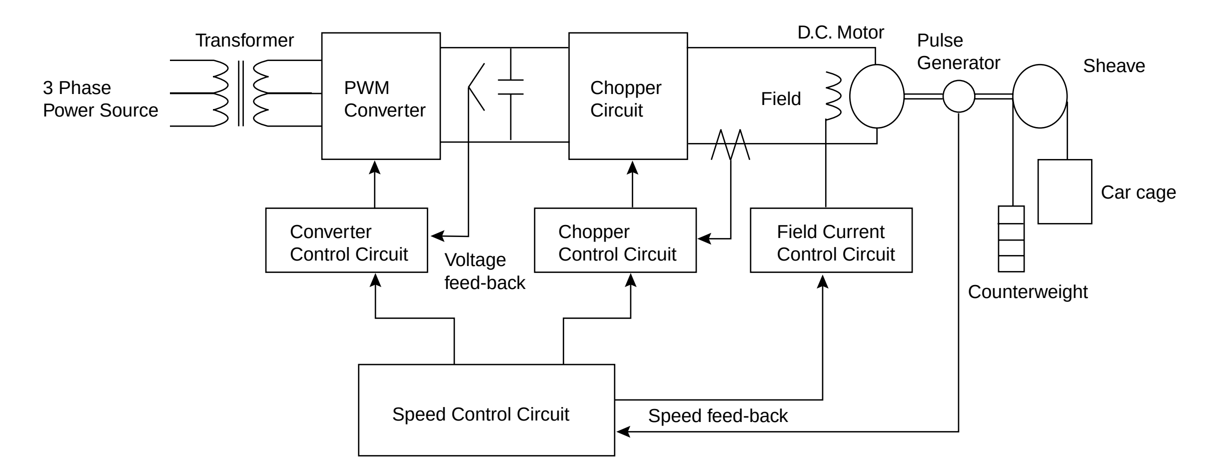


Fig. 1 Control system configuration.

*Toru Tanahashi and Masami Kawamura are with the Inazawa Works.

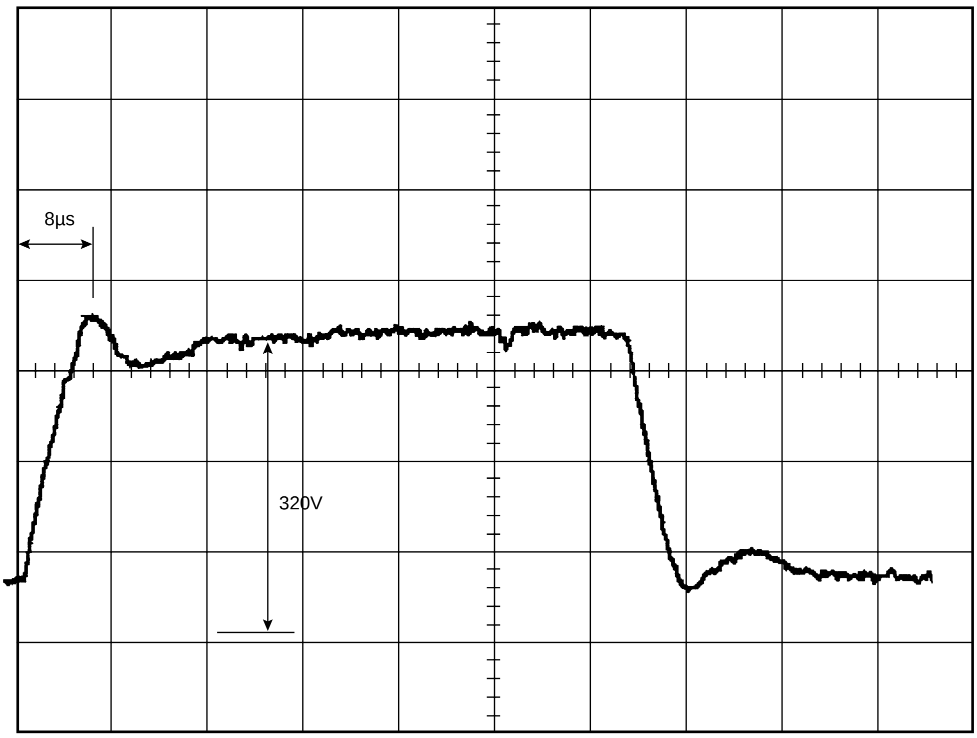


Fig. 3 Surge voltage waveform.

reduce the substation capacity requirement by 20~30% compared to a thyristor Leonard circuit. The transformer at the PWM converter input provides electrical isolation that protects other equipment in the building from damage by leakage currents originating in the elevator.

The chopper circuit employs an H-shaped network permitting full four-quadrant control. Powering and regenerative braking are available during both ascent and descent. The chopper circuit also uses parallel-connected 1,200V 600A IGBTs to perform the power switching. The large amount of heat in the IGBTs, generated by the flow and switching of high DC currents, is carried away by compact heat sinks using heat-pipe technology.

Steep voltage gradients that occur during IGBT switching can cause voltage ringing that propagates through the output cable causing voltage surges in the motor's armature winding. IGBTs can turn on or turn off in less than 0.1 microsecond. Surge voltages from this fast switching can build up potential differences between the armature windings high enough to cause dielectric breakdown, arcing and damaging the insulation. Older motors with declining insulation resistance are especially subject to this type of damage.

An LCR filter on the chopper circuit output limits this danger by lengthening the rise time of surge voltage and lowering peak voltage. Fig. 3 shows current transients at the armature winding terminals when the IGBT turns on. The surge has a long, eight-microsecond rise time that limits inductive effects. As a result the peak voltage drops dramatically, rising scarcely 5% above the DC bus voltage.

With thyristor Leonard circuits, the armature current includes a ripple at a frequency six times that of the power source, or 300~360Hz -representing electromagnetic energy that causes audible noise. In the chopper system, a modulation frequency of 5kHz results in a high ripple frequency that is attenuated by the impedance of the armature winding, reducing audible noise.

Control Circuit

A high-performance VLSI microprocessor developed to control inverter-controlled high-speed elevators has been adapted to this DC application. A pulse generator on the motor shaft provides speed detection for the main feedback loop. Speed control accuracy is further enhanced by a second feedback loop that senses the armature current. The microprocesssor program for controlling the chopper circuit performs calculations to suppress elevator vibration, thus improving riding comfort by reducing noise and vibration.

In DC elevators, the current in the field winding is often controlled to vary with elevator velocity. This method results in torque variations that can cause the car to vibrate. The new system's control program minimizes these torque pulsations by coordinated control of the field current and armature current.

Fig. 4 shows the speed and acceleration curves for the elevator operating at rated load capacity. The acceleration is as smooth as in the latest inverter-controlled elevators, with greater ride comfort than previous control systems using a motor-generator (MG) set. A pulse encoder on the governor detects car position to within 0.5mm and dramatically improves landing accuracy.

Other Features

The new control system has cut energy use by

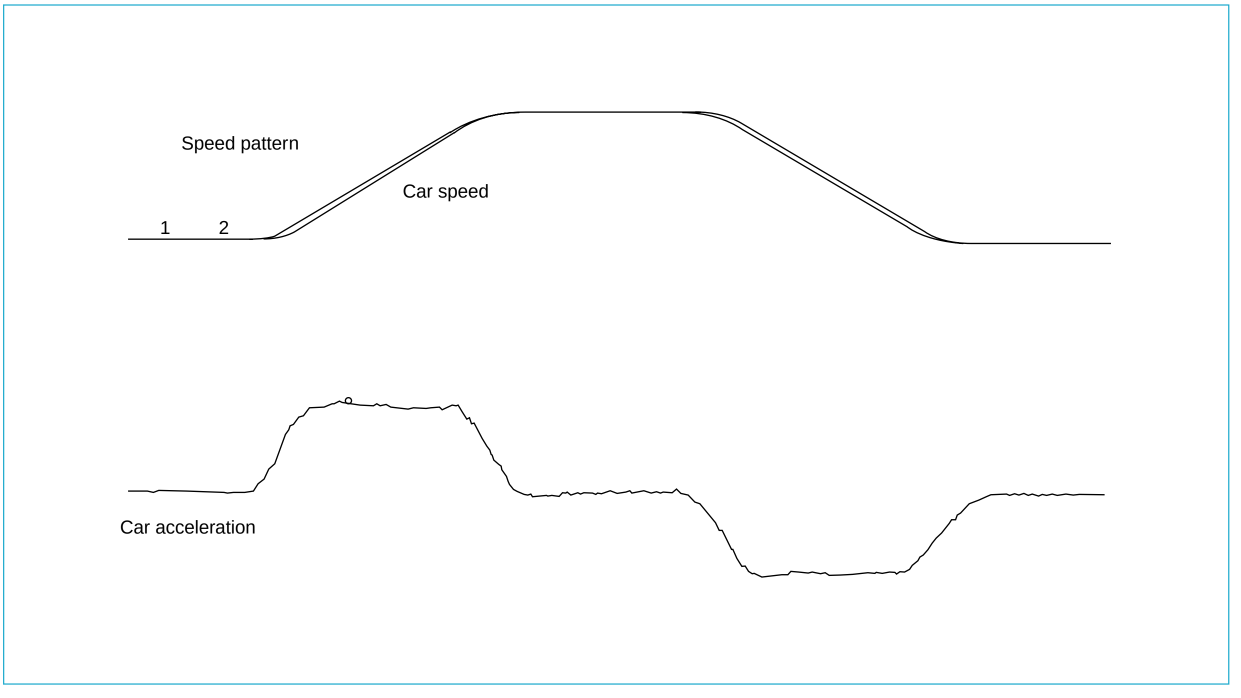


Fig. 4 Car speed and acceleration under full load.

Fig. 5 Control panel.

40% compared to an MG control system. Replacing the MG circuit by a chopper circuit has reduced energy losses 20%. Another 5% power saving comes from replacing relays with microprocessor control. A final 5% saving comes from more efficient motor operation.

Mitsubishi Electric Model AI-2100N group control system is available for modernization to manage multiple elevators. The system uses artificial intelligence and neural network technologies. Many other options of Mitsubishi GPM Series elevators are also available.

When elevators are updated with a new control system, the new control panel is carried to the machine room through the interior of the building. The control panel, shown in Fig. 5, is divided into upper and lower parts to facilitate transport through constricted locations.

With the control system described here, older DC high-speed elevators can be upgraded to efficiency and rider comfort levels approaching those of the latest AC high-speed elevators. ❑

New Elevators for Residential Use

*by Yoshio Kamiya and Hiroshi Hirano**

Mitsubishi Electric's "Well Family" Series of residential elevators save space by locating the guide rails on the side of the elevator shaft near the traction unit. The elevators offer two car ceiling designs, three designs for the elevator hall and exterior doors, and a variety of other options.

Features

The new elevators offer significant improvements over previous models.

SMALLER. The cross section of the elevator shaft was reduced to 1.89m² for a three-person model, a savings of 10% in installation area compared to the product it replaces.

QUIETER. Noise and vibration levels have also been reduced, making the elevators better suited to residential use. Smaller gaps and level differences at the door threshold facilitate cart and wheelchair access.

CLEANER. To address environmental concerns, recyclable specialty plastics replace polyvinyl chloride-metal laminated sheet in wall and ceiling liners, cosmetic panels and decorative accents. Bacteria-resistant plastics help keep the control panel and call buttons clean and hygienic.

OPTIONS. Several design and color variations are available for the cars and elevator halls. Cars can be provided with dual exits, an option available for the first time in two-passenger models.

Construction

Fig. 1 shows a perspective view of the new elevator, Fig. 2 a plan view of several shaft designs. As with previous residential elevators, the traction unit is installed at the bottom of the shaft with the lift cable passing over a pulley at the top of the shaft and down to the car.

The shaft cross section needed for a given size car has been reduced by moving the guide rails to one side of the shaft and by modifying the traction unit mounts. The pit depth is unchanged. The space efficiency of a three-person elevator-the ratio of the car floor area to the shaft cross section area-has been boosted by ten percentage points to 57%.

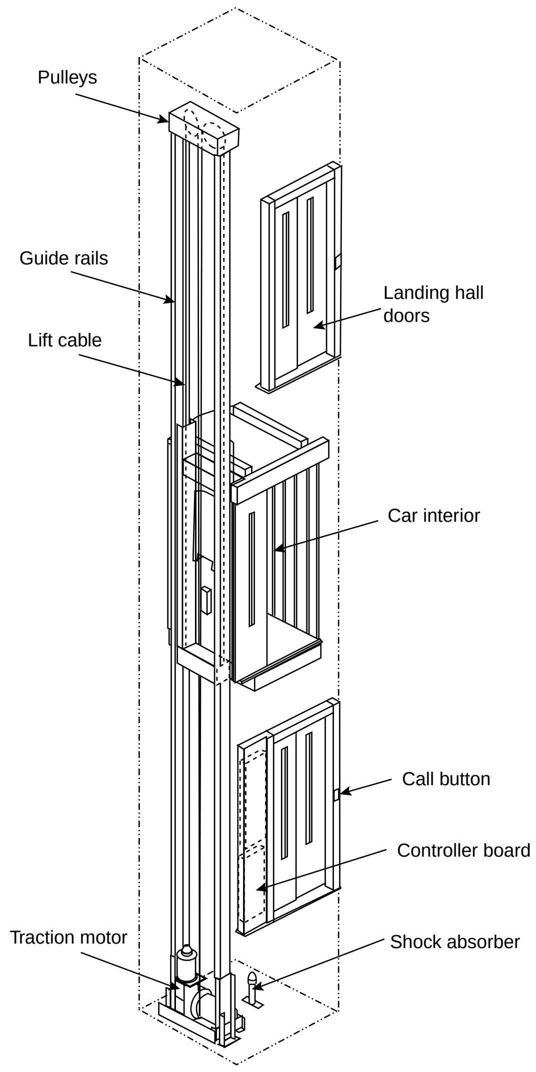


Fig. 1 Elevator construction.

A standardized design permits shared parts among various configurations that include two- and three-passenger capacity cars, single- and dual-entrance cars, right- and left-opening doors, and installations in wood frame, steel frame and reinforced concrete structures. Wood frame installations benefit from a shaft cross section that

Yoshio Kamiya is with Inazawa Works and Hiroshi Hirano is with Mitsubishi Electric Elevator Products Co., Ltd.

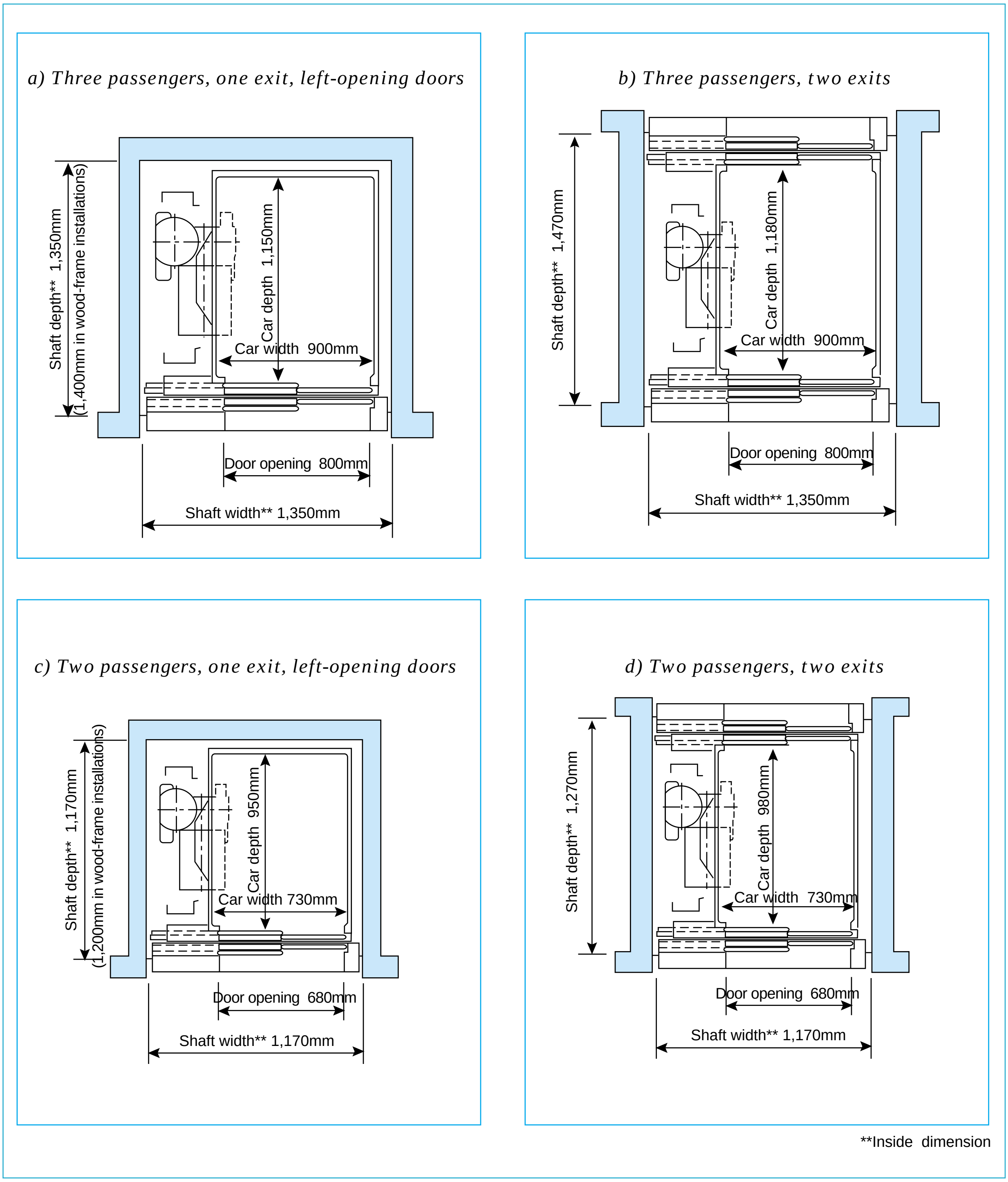


Fig. 2 Plan views of the elevator shaft.

is almost identical to that for other construction methods.

The size of the control panel for the new elevators has been reduced, allowing it to be placed inside the open side door jamb at the landing of the lowest floor. The control panel can be removed via the door jamb inspection port with wiring connected, allowing maintenance to be conducted in the hallway. This approach saves space and improves the landing's aesthetic appearance by eliminating the need for a removable door-retraction-bay wall.

Fig. 3 shows the basic electrical configuration. The elevators now use a 200VAC single-phase power supply-available in most homes-instead of the three-phase supply previously required. The inverter is implemented using an intelligent power module, as in previous residential elevators, but with a redesigned mounting that is more compact and reliable than before.

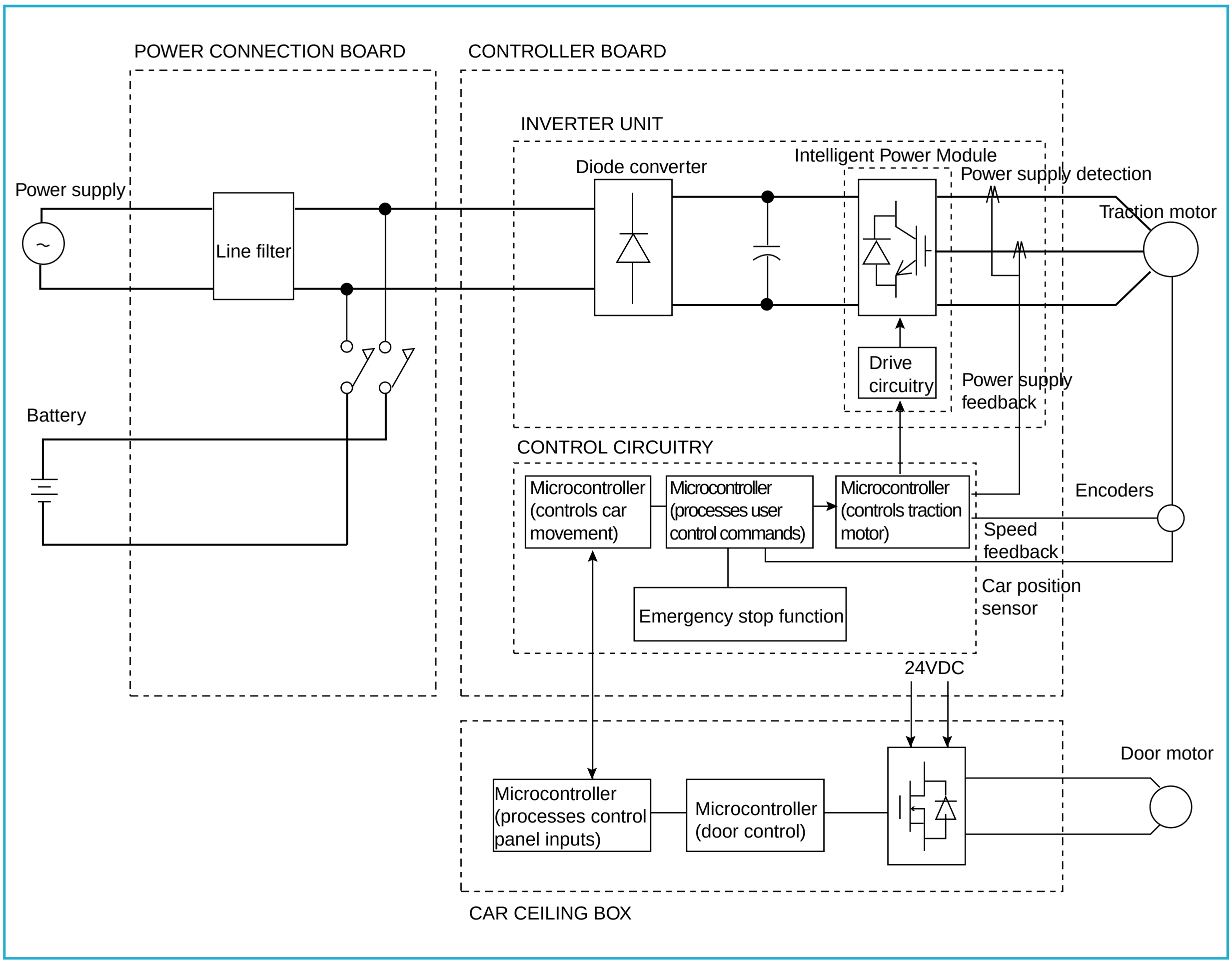


Fig. 3 Electrical system configuration.

A high-performance monolithic microprocessor generates control signals for the inverter using digital control programs designed to optimize comfort and safety.

Included in all models is a battery-powered emergency-stop function that lowers the car to the next landing if a blackout or other failure disrupts the main power supply while the car is between floors. Circuitry for the function has been moved onto the main controller board from a separate board in the controller box. The power connection board for the elevator has been moved into the door retraction bay in the elevator hallway at the bottom floor. The board also includes low-maintenance components that previously resided on the controller board. A line filter is provided to prevent electromagnetic noise generated in the inverter from affecting other home appliances.

Control functions are implemented using a distributed processing model. Two microprocessors managing the elevator car are located on a circuit board mounted in the car ceiling. One sends commands from the car's control panel to the elevator controller board and operates the lights and exhaust fan. The second generates PWM signals for the DC-motor-operated doors. The deceleration and landing switches located on the guide rails at each floor are combined into single units that simplify installation and adjustment.

The initial cars have been made of glass-fiber reinforced plastic (GFRP) but this is to be replaced by a recyclable specialty plastic that is 20% lighter than GFRP. The specialty plastic has a coefficient of thermal expansion that is four times that of GFRP, making the car potentially liable to warping due to temperature changes. Various structural designs were tested under controlled temperature and humidity conditions in a large test chamber and a configuration with minimal warping was selected.

A telephone handset provided as standard equipment serves day-to-day and emergency communication needs.

Aesthetic and Ergonomic Design

Elevators for home use should use tranquil, relaxing color schemes that blend well with home

Fig. 4 Car interior.

interiors while offering various options to suit individual tastes.

Fig. 4 shows the elevator car interior. Vertical stripes from floor to ceiling establish a sense of unity, while an arched ceiling and recessed control panel contribute to a feeling of space.

Fig. 5 shows the elevator hall. Environmental considerations have led to the replacement of the PVC cosmetic paneling previously used by printed steel sheet. The call buttons can be mounted for access by wheelchair users, or at any height the customer specifies.

Fig. 6 shows the control panel. Large convex buttons labeled with highly legible symbols facilitate use by the young, elderly and those with

Fig. 5 Elevator hall.

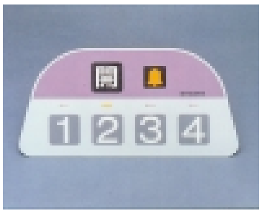


Fig. 6 Control panel.

Fig. 7 Handrail.

Fig. 8 Mirror.

impaired vision. The cars can be optionally fitted with a choice of three types of handrails and three types of mirrors, an increase over the previous single-choice options. Fig. 7 shows a handrail and Fig. 8 a mirror. The L-shaped handrail facilitates wheelchair access and assisted walking.

A full-color painting option previously available for custom manufactured products is now available for the car's rear wall. The rear wall can also be fitted with an observation window.

This latest generation of residential elevators offers an aesthetic and cost-effective solution to improving access to individual homes. ❑

A Remote Inspection System for Elevators

*by Kiyoji Kawai and Hideki Shiozaki**

Mitsubishi Electric has developed a remote inspection system that monitors elevator operation continuously over leased and PSTN lines. Downtime is reduced because the elevator operating conditions can be inspected without interrupting passenger services. The system gathers data frequently, allowing problems to be recognized early and remedied promptly. The authors report on this system and operating experiences in Japan.

Fig. 1 illustrates the system configuration and basic operating concepts. Each elevator is fitted with a remote inspection unit and a communications controller that is linked to a computer at the remote monitoring center and to terminals in service facilities via PSTN and leased lines.

The remote inspection unit has various measurement, monitoring and diagnostic functions that replace most field inspection items. Data can be logged internally. The unit also has control functions that can invoked from the monitoring center. Data gathered by the unit can be used to generate optimal maintenance schedules and can serve as a basis for client consulting services.

The communications controller exchanges data with the remote inspection unit, operates the elevator car's intercom link to the monitoring center, and has modem and line control capabilities for data communications with the monitoring center.

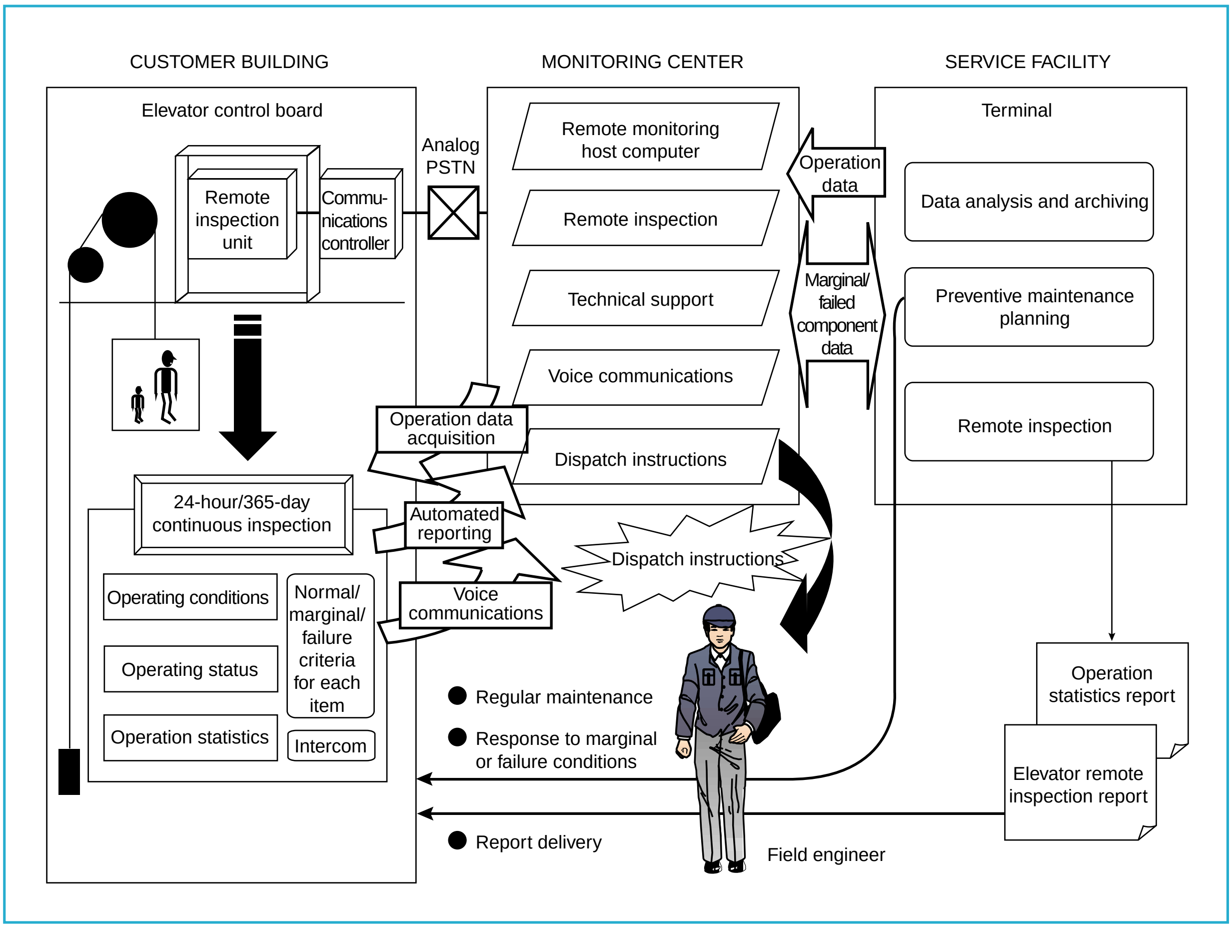


Fig. 1 Basic concepts of the remote inspection system.

**Kiyoji Kawai is with Inazawa Works and Hideki Shiozaki with Mitsubishi Electric Building Techno-Service Co., Ltd.*

Fig. 2 A photograph of the monitoring center.

The central monitoring host is a computer located in the monitoring center. It is independent, with its own control desk. Fig. 2 is a photograph of the control room.

The terminals are computers installed in service facilities that provide service personnel access to elevator operation data logs on the host computer. The terminals can check current elevator operating parameters and review detailed inspection data. They also have report-generation functions that list remote inspection results and generate instructions for the field engineer.

As of November 1999, the remote inspection system covers 14 types of elevators beginning with the company's first microprocessor-controlled models and extending to current products. The latest elevators have these capabilities built-in. Earlier models can be retrofitted.

System Functions

The system tracks marginal conditions as well as failures, collecting more comprehensive and revealing data than on-site inspections, see Fig. 3. For our purposes, a marginal condition is de-

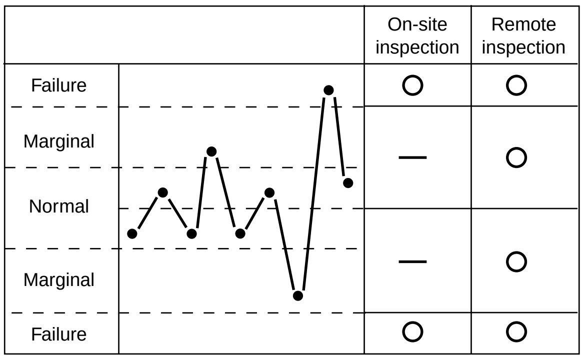


Fig. 3 Normal, marginal and failure indications.

Table 1 Major Remote Inspection Items

Machine room temperature
Brake valve status
Contactor status
Control electronics
Car operation during startup, travel and landing.
Landing accuracy
Car interior illumination
Emergency light bulb continuity and battery voltage
Door opening and closing times and safety functions, overload detector.
Door switch operation
Intercom power voltage
Operation of door open, door close and destination buttons.
Call button operation
Landing switch operation
Safety switch operation

Table 2 Major Measurement Items

Measurement item	Service item
No. of trips	Brake equipment
Cumulative operating time	Guide shoes
Cumulative distance	Traction motor gear oil
Contactor operation count	Control equipment
Door operations, overall and per floor	Door equipment
Car interior illumination startups and interior illumination time	Lamp bulbs and circuits
Hall indicator illumination time (per floor)	Related bulbs
Direction indicator illumination time (per floor)	Related bulbs
Hoist cable flex count	Hoist cable

Table 3 Operation Statistics

Hall calls	Sorted by floor and direction
Car calls	Sorted by floor
No. of passengers boarding or leaving	Sorted by floor and elevator direction
Passenger waiting times	Sorted by floor and direction
Power consumption	-

fined as an failure that is resolved by a retry within the context of normal operation. Mechanical wear and contamination can affect relay contacts causing occasional recoverable logic errors. The early warning provided by these symptoms can be useful to ensure that full equipment functionality is available at all times. Detailed tracking of the progress of these conditions provides data that can be analyzed to model failure mechanisms, predict failures, and generate cost-effective maintenance schedules that combine regular maintenance and timely intervention.

There are three types of diagnostic function. One of these can be performed while the elevator is delivering passenger services, and corresponds with the kind of parameters a field engineer would come to inspect. These are listed in Table 1. The second type includes braking tests, door operation tests and other sophisticated procedures that can identify impending failures in their early stages. These are performed regularly, generally late at night when there are few passengers. A third type is an operation test performed under remote supervision by an engineer. These tests reveal many details about the condition of the control electronics, tractor motor and hoist mechanism that were previously time-consuming to diagnose.

REGULAR INSPECTION AND MAINTENANCE ITEMS. Elevator maintenance and component replacement schedules are based on the cumulative number of elevator trips, time under power, and number of door openings at each floor. This information is combined with data on wear and failure rates. Service interruptions are reduced by scheduling inspections, routine maintenance and component replacement to be conducted concurrently. Table 2 lists measurement, maintenance and replacement items.

OPERATION STATISTICS CONSULTING. Elevator operation statistics are important to a building owner or manager because they reveal how people are moving through the building and how many are visiting which floors. Statistics are also important to demonstrate that the elevator sys-

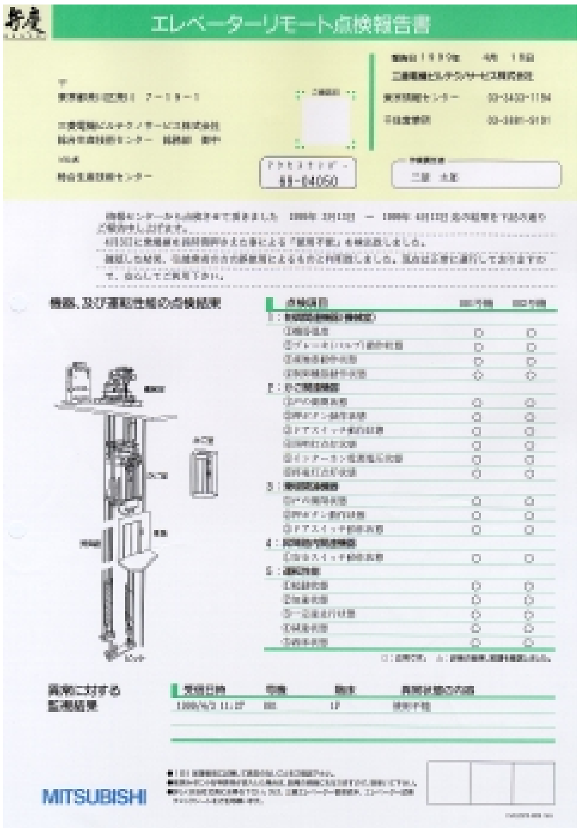


Fig. 4 An elevator remote inspection report.

tems are achieving their service goals. The remote inspection unit also includes several functions for monitoring traffic statistics and delivering the information in timely manner. Table 3 lists key items.

CUSTOMER REPORTS. Data gathered by the online inspection system is delivered to customers as monthly inspection reports and regular operation statistics. The monthly inspection report is generated automatically and is printed by the terminal. It shows item by item the various normal, marginal and failure conditions. Fig. 4 shows a typical report.

The addition of remote inspection capabilities to elevator systems helps to improve system availability while reducing maintenance costs. These capabilities are available for new as well as existing installations. ❑

The FPR-MKII Finger Print Recognizer

The FPR-DTMKII Fingerprint Recognizer for Personal Computers.

The new products in the FPR-MKII series of Mitsubishi Electric's small Finger Print Recognizers were marketed in April 1998. The series consists of low-price, compact units with simple verification procedures for great ease and convenience in use.

This is achieved by implementing image processing and verification on a single-chip RISC CPU while at the same time significantly reducing the circuit component count by directly employing the digital signal from the video sensor. The volume of these units is accordingly only one fifth that of the corporation's previous models, and the price, one third.

Again, the adoption of a faster and more accurate verification algorithm has made it possible to provide an auto-verification function. This function automatically compares the input fingerprint with all those previously recorded and identifies whether or not it is to be found among them. This has the practical advantage of dispensing with the previously obligatory need to enter an ID number. Identification is possible at the touch of a finger, greatly simplifying the whole procedure.

The series consists of two types: one is for access control of restricted areas and the other is for connection to a personal computer. The access control units lock and unlock doors under fingerprint control to deny or permit access to certain areas. Three types are available: the FPR-200ADMKII provides for control of one door and 200 fingerprints; the FPR-1000ADMKII for one door and 1,000 fingerprints; and the FPR-1000CSMKII for four doors and 1,000 fingerprints.

The unit for personal computer terminals is the FPR-DTMKII. This, as shown in Fig. 1, is placed on the desk beside the computer. Fingerprints can then be used instead of passwords to authenticate users signing onto the computer or the network. This eliminates the forgetting—and stealing—of passwords, greatly enhancing both convenience and security. ❑

MITSUBISHI ELECTRIC OVERSEAS NETWORK (Abridged)

Country	Address		Telephone
U.S.A.	Mitsubishi Electric America, Inc.	5665 Plaza Drive, P.O. Box 6007, Cypress, California 90630-0007	714-220-2500
	Mitsubishi Electric America, Inc. Sunnyvale Office	1050 East Arques Avenue, Sunnyvale, California 94086	408-731-3973
	Mitsubishi Electronics America, Inc.	5665 Plaza Drive, P.O. Box 6007, Cypress, California 90630-0007	714-220-2500
	Mitsubishi Consumer Electronics America, Inc.	9351, Jeronimo Road, Irvine, California 92618	949-465-6000
	Mitsubishi Semiconductor America, Inc.	Three Diamond Lane, Durham, North Carolina 27704	919-479-3333
	Mitsubishi Electric Power Products Inc.	512 Keystone Drive, Warrendale, Pennsylvania 15086	724-772-2555
	Mitsubishi Electric Automotive America, Inc.	4773 Bethany Road, Mason, Ohio 45040	513-398-2220
	Astronet Corporation	3805 Crestwood Parkway Suite 400 Duluth, Georgia 30096	770-638-2000
	Powerex, Inc.	Hills Street, Youngwood, Pennsylvania 15697	724-925-7272
	Mitsubishi Electric Information Technology Center America , Inc.	201 Broadway, Cambridge, Massachusetts 02139	617-621-7500
Canada	Mitsubishi Electric Sales Canada Inc.	4299 14th Avenue, Markham, Ontario L3R 0J2	905-475-7728
Mexico	Melco de Mexico S.A. de C.V.	Mariano Escobedo No. 69,Tlalnepantla, Edo. de Mexico Apartado Postal No.417, Tlalnepantla	5-565-4925
Brazil	Melco do Brazil, Com. e Rep. Ltda.	Av. Rio Branco, 123, S/1504-Centro, Rio de Janeiro, RJ CEP 20040-005	21-221-8343
	Melco-TEC Rep. Com. e Assessoria Tecnica Ltda.	Av. Rio Branco, 123, S/1507, Rio de Janeiro, RJ CEP 20040-005	21-221-8343
Argentina	Melco Argentina S.A.	Florida 890-20-Piso, Buenos Aires	1-311-4801
Colombia	Melco de Colombia Ltda.	Calle 35 No. 7-25, P.12 A. A. 29653 Santafe de Bogota, D.C.	1-287-9277
U.K.	Mitsubishi Electric U.K. Ltd. Livingston Factory	Houston Industrial Estate, Livingston, West Lothian, EH54 5DJ, Scotland	1506-437444
	Apricot Computers Ltd.	3500 Parkside, Birmingham Business Park, Birmingham, B37 7YS, England	121-717-7171
	Mitsubishi Electric Europe B.V. Corporate Office	Centre Point (18th Floor), 103 New Oxford Street, London, WC1A 1EB	171-379-7160
France	Mitsubishi Electric France S.A. Bretagne Factory	Le Piquet 35370, Etrelles	2-99-75-71-00
The Netherlands	Mitsubishi Electric Netherlands B.V.	3rd Floor, Parnassustoren, Locatellikade 1, 1076 AZ, Amsterdam	020-6790094
Belgium	Mitsubishi Electric Europe B.V. Brussels Office	Avenue Louise 125, Box 6, 1050 Brussels	2-534-3210
Germany	Mitsubishi Electric Europe B.V. German Branch	Gothaer Strasse 8, 40880 Ratingen	2102-4860
	Mitsubishi Semiconductor Europe GmbH	Konrad-Zuse-Strasse 1, D-52477 Alsdorf	2404-990
Spain	Mitsubishi Electric Europe B.V. Spanish Branch	Polígono Industrial "Can Magí", Calle Joan Buscallà 2-4, Apartado de Correos 420, 08190 Sant Cugat del Vallês, Barcelona	3-565-3131
Italy	Mitsubishi Electric Europe B.V. Italian Branch	Centro Direzionale Colleoni, Palazzo Persero-Ingresso 2, Via Paracelso 12, 20041 Agrate Brianza	39-60531
China	Mitsubishi Electric (China) Co., Ltd.	Room No. 1609 Scite Building (Noble Tower), Jianguo Menwai Street, Beijing	10-6512-3222
	Mitsubishi Electric (China) Co., Ltd. Shanghai Office	39th Floor, Shanghai Senmao International Building, 101, Yincheng Road (E), Pudong New Area, Shanghai	21-6841-5300
	Mitsubishi Electric (China) Co., Ltd. Guangzhou Office	Room No. 1221-4, Garden Tower, Garden Hotel, 368, Huanshi Dong Lu, Guangzhou	20-8385-7797
	Shanghai Mitsubishi Elevator Co., Ltd.	811 Jiang Chuan Road, Minhang, Shanghai	21-6430-3030
Hong Kong	Mitsubishi Electric (H.K.) Ltd.	41st Floor, Manulife Tower, 169 Electric Road, North Point	2510-0555
	Ryoden (Holdings) Ltd.	10th Floor, Manulife Tower, 169 Electric Road, North Point	2887-8870
	Ryoden Merchandising Co., Ltd.	32nd Floor, Manulife Tower, 169 Electric Road, North Point	2510-0777
Korea	KEFICO Corporation	410, Dangjung-Dong, Kunpo, Kyunggi-Do	343-51-1403
Taiwan	Mitsubishi Electric Taiwan Co., Ltd.	11th Floor, 88 Sec. 6, Chung Shan N. Road, Taipei	2-2835-3030
	Shihlin Electric & Engineering Corp.	75, Sec. 6, Chung Shan N. Road, Taipei	2-2834-2662
	China Ryoden Co., Ltd.	Chung-Ling Bldg., No. 363, Sec. 2, Fu-Hsing S. Road, Taipei	2-2733-3424
Singapore	Mitsubishi Electric Singapore Pte. Ltd.	152, Beach Road, #11-06/08, Gateway East, Singapore 189721	295-5055
	Mitsubishi Electric Sales Singapore Pte. Ltd.	307, Alexandra Road, #05-01/02, Mitsubishi Electric Building, Singapore 159943	473-2308
	Mitsubishi Electronics Manufacturing Singapore Pte. Ltd.	3000, Marsiling Road, Singapore 739108	269-9711
	Mitsubishi Electric Asia Co-ordination Centre	307, Alexandra Road, #02-02, Mitsubishi Electric Building, Singapore 159943	479-9100
Malaysia	Mitsubishi Electric (Malaysia) Sdn. Bhd.	Plo 32, Kawasan Perindustrian Senai, 81400 Senai, Johor Daruel Takzim	7-5996060
	Antah Melco Sales & Services Sdn. Bhd.	No.6 Jalan 13/6, P.O. Box 1036, 46860 Petaling Jaya, Selangor, Daruel Ehsan	3-755-2088
	Ryoden (Malaysia) Sdn. Bhd.	No. 14 Jalan 19/1, 46300 Petaling Jaya Selongar Daruel Ehsam	3-755-3277
Thailand	Kang Yong Watana Co., Ltd.	28 Krungthep Kreetha Road, Huamark, Bangkapi, Bangkok 10240	2-731-6841
	Kang Yong Electric Public Co., Ltd.	67 Moo 11, Bangna-Trad Road KM. 20, Bangplee, Samutprakarn 10540	2-337-2431
	Melco Manufacturing (Thailand) Co., Ltd.	86 Moo 4, Bangna-Trad Road KM. 23, Bangsaothong, Samutprakarn 10540	2-312-8350~3
	Mitsubishi Elevator Asia Co., Ltd.	700/86~92, Amata Nakorn Industrial Estate Park2, Moo 6, Bangna-Trad Road, Tambon Don Hua Roh, Muang District, Chonburi	38-213-170
	Mitsubishi Electric Asia Coordination Center (Thailand)	17th Floor, Bangna Tower, 2/3 Moo 14, Bangna-Trad Highway 6.5 Km, Bangkawe, Bang Plee, Samutprakarn 10540	2-312-0155~7
Philippines	International Elevator & Equipment, Inc.	K.m. 23 West Service Road, South Superhighway, Cupang, Muntinlupa, Metro Manila	2-842-3161~5
Australia	Mitsubishi Electric Australia Pty. Ltd.	348 Victoria Road, Rydalmere, N.S.W. 2116	2-9684-7777
New Zealand	Melco New Zealand Ltd.	1 Parliament St., Lower Hutt, Wellington	4-560-9100
Representatives			
Korea	Mitsubishi Electric Corp. Seoul Office	Daehan Kyoyuk Insurance Bldg., Room No. 2205, #1,1-ka, Chongno-ku, Seoul	2-732-1531~2
India	Mitsubishi Electric Corp. New Delhi Liaison Office	Dr. Gopal Das Bhawan (8th Floor), 28 Barakhamba Road, New Delhi 110001	11-335-2343
Viet Nam	Mitsubishi Electric Corp. Ho Chi Minh City Office	18th Floor, Sun Wah Tower, 115 Nguyen Hue Street, District 1, Ho Chin Minh City	8-821-9038

MITSUBISHI ELECTRIC CORPORATION
HEAD OFFICE: MITSUBISHI DENKI BLDG., MARUNOUCHI, TOKYO 100-8310, FAX 03-3218-3455