Mitsubishi's GPQ Machine Room Less Elevator For The European Market

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ABSTRACT

Mitsubishi has developed a machine room less elevator – the GPQ – for the European market, which combines high quality and high performance with greater freedom of building design, due to less restrictions. A variety of safety measures ensure the safety of both passengers and maintenance personnel up to a safety level as demanded by European regulations. As a result of that, the GPQ elevator system has passed the EC-type examination.

1 INTRODUCTION

Mitsubishi has developed the Mitsubishi machine room less Elevator GPQ. The equipment of that GPQ, which would normally be installed in a separate machine room, is now located in the pit. This allows the building to be constructed with fewer restrictions regarding space requirements and height. The machine being located in the pit results in a low level of noise emission towards spaces adjacent to the hoist way. Suspension of the hoisting ropes by the guide rails results in the system loading being transmitted to the pit floor alone, rather than through the building.
A highly efficient permanent magnet motor is used in combination with a gear less traction machine. This results in high performance and high quality.
Special safety measures were developed in order to ensure safety for the maintenance person and passengers. The safety level of the GPQ was evaluated and approved by means of EC-type-certification procedure according to the new European Liftsdirective.

The GPQ is a side-drop lift with 2:1 underslung roping, and the PM gearless machine located in the pit. The available range is shown Table 1.

Table 1: Available range of GPQ elevators

Capacity	8 persons (630kg) 10 persons (800kg) 14 persons (1050kg)
Speed	1.0 m/s; 1.6 m/s
Maximum travel	30 m
Maximum number of stops	12 stops

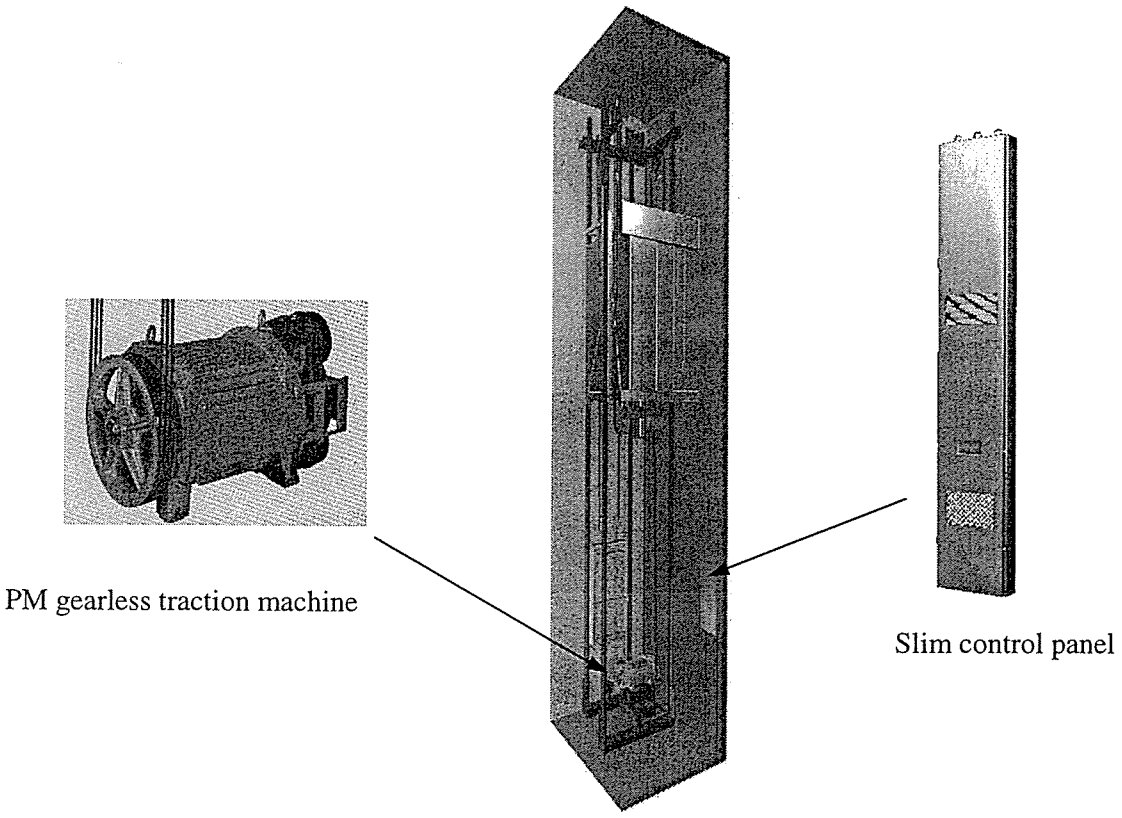

Figure 1: The GPQ concept

2 PRODUCT FEATURES

2.1 Fewer Restrictions To The Building

(1) Reduced space requirement – A comparison between the installation space for the GPQ and other elevator types is shown in Table 2. The need for a conventional machine room disappeared by installing the equipment, including the traction machine, control panel and governor in the hoistway. By simultaneously reducing the hoistway area a total reduction of the required floor area was achieved of approx. 23% and 33 %, when compared to the hydraulic type and the conventional traction type elevators. The overhead dimensions are the same as those of the hydraulic type. By these improvements compliance with height restrictions is easier, freedom of the overall building design is enhanced and the rentability of the entire building is increased.

Table 2: Space requirements

Elevator Type		GPQ	Hydraulic	Traction
Hoist Way (A)	Width x Depth [m]	1.67x1.82	1.67x1.82	1.67x2.01
	Area [m2]	15.20	15.20	16.78
Machine Room (B)	Width x Depth [m]	Not applicable	2.4x1.9	1.84x3.15
	Area [m2]	0	4.56	5.80
Total Area [m2] (A) + (B)		15.20	19.76	22.58
Overhead [mm]		3700	3750	3950

Comparison of residential elevators: 8 persons, 60 m/min, 5 stops

(2) Reduced structural loading – the ends of the hoisting ropes are fixed at the top of the guide rails on both the car and counterweight sides. Furthermore the traction machine is fixed to the lower parts of the guide rails. Thus the total construction is self supportive and the entire weight of the elevator system is supported by the pit surface, rather than the building, allowing for improved freedom of building design.

(3) Universal appearance – the GPQ elevator system is available with the same wide range of appearance options as conventional systems. Such options encompass the appearances of hall entrances and car interiors, and support for increased accessibility for the elderly and disabled.

(4) Low noise emission – through the location of the traction machine in the pit, lower levels of noise emission are detected in spaces adjacent to the hoist way. This allows for greater freedom of building design in that the architect can position the elevator shaft next to noise critical rooms, such as in residential building and hotels.

2.2 High Performance And High Quality

(1) Efficiency – A comparison between the levels of energy consumption of the GPQ and other elevator types is shown in Table 3. By the use of a gearless traction machine in combination with a highly efficient PM motor, energy consumption is reduced by approximately 65% compared to the hydraulic type, and approximately 20% compared to the conventional traction type.

Table 3: Power requirements

Elevator Type	GPQ	Hydraulic	Traction
Motor Output [kW]	3.7	18.5	4.5
Power Supply [kVA]	4	24	5
Power consumption, p.a. [kWh]	2590	7470	2876

Comparison of residential elevators: 8 persons, 60 m/min, 5 stops

(2) Riding comfort – By using a quiet, highly efficient and highly responsive PM motor and advanced motor control technology, a smooth ride is achieved, comparable to that of a high-speed elevator.

2.3 Ensuring safety

(1) Maintenance in the pit – Due to the fact that the basic equipment is located in pit, that location can be regarded as an alternative machine room. Measures were taken in order to ensure an equal level of safety for the maintenance person as is provided by a conventional machineroom. The maintenance person can enter the pit of the GPQ, close the landing door behind him, and start the maintenance task. The work will not be interfered by passers by, or persons working on the elevator from a different location.

(2) Maintenance from the landing floor – Some maintenance tasks, like dynamic tests, are impossible to be performed from inside the shaft. A hall inspection panel as shown in Figure 2 provides the necessary controls in order to perform these tasks. A key is required to open the hall inspection panel. The contents of it are kept to a minimum in order to minimize reciprocal interference with passers-by. Important functions for example are electric operation, remote tripping the governor, releasing the brakes and resetting the lift.

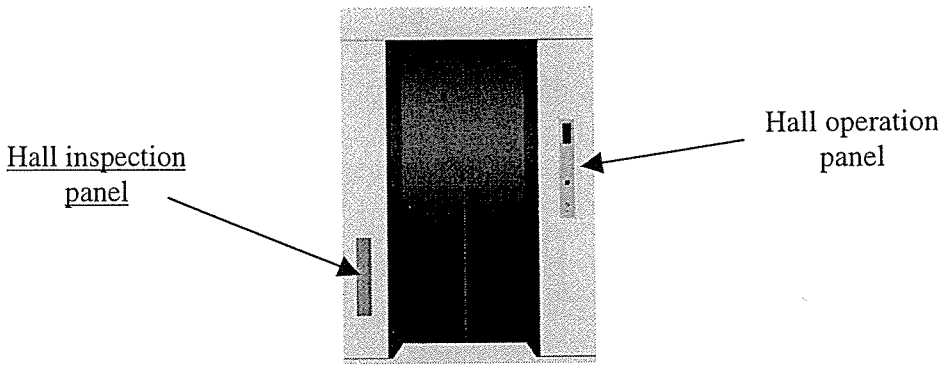

Figure 2: The Hall Inspection panel at the lowest landing

(3) Rescuing of passengers being trapped – If passengers are trapped in the car, these can be rescued from outside the shaft. The necessary tools and controls are located in the hall inspection panel at the lowest landing floor. The hall operation device enables electric emergency operation. If for some reason that is not possible, the brakes of the PM machine can be released from the hall inspection panel by a brake release lever which is connected to the machine brakes by means of wire rope.

3 PRODUCT CONFIGURATION

3.1 Layout

A vertical cross section and a layout plan of the GPQ pit are shown in Figure 3. The basic configuration consists of a traction machine installed at the bottom of the vertical guide rail, and deflection sheave installed at the top. The car is suspended to the hoisting ropes by means of two suspension sheaves fixed to the bottom of the car. The counterweight is suspended in a similar way by means of a suspension sheave on top of it. This configuration is referred to as the 2:1 roping underslung basement method, which is effective when minimizing the upper dimensions of the building. The ends of the hoisting ropes are fixed at the top of the guide rail on both the car and counterweight sides. As a result the entire weight of the elevator system is supported by the pit surface. The upward and downward forces, due to the traction machine and support sheaves, are transmitted through the guide-rails, so that these loads are not supported by the building.

A newly developed slim control panel is installed in the hoistway in the limited space between the car and the wall.

EN81-1 defines a variety of clearance and free space dimensions in the pit, when the car is resting on it's compressed buffer. In addition, EN349 defines safety distances in order to avoid crushing. In accordance with both of these standards, the following measures were undertaken:

- The traction machine was placed parallel to the angled underslung assembly, with a safety distance of 500mm between them.
- A low machine bed was developed.
- The car apron folds away from the machine when the car hits the buffer.
- A low buffer footing was developed.

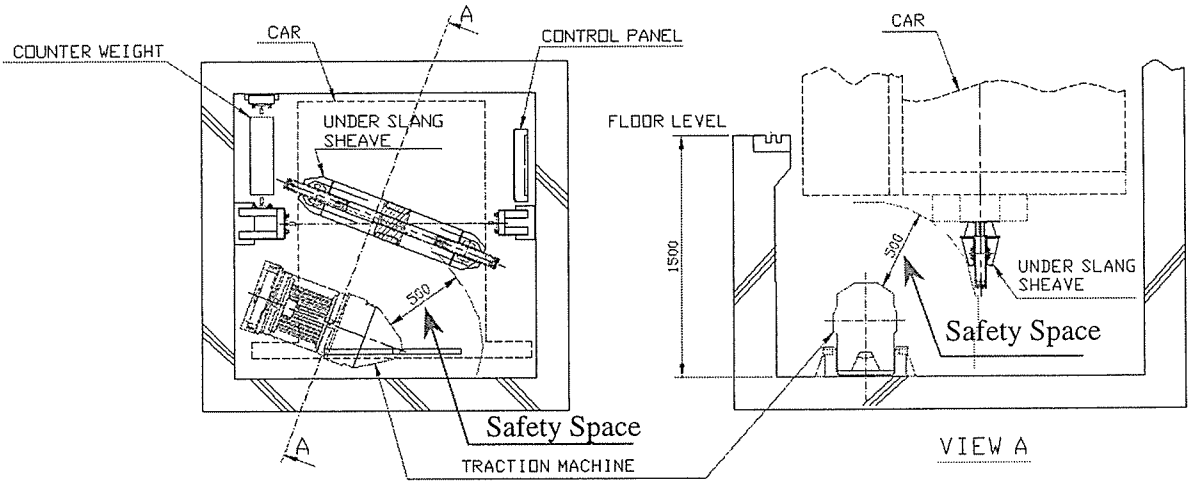

Figure 3: A cross section and a layout plan of the pit of the GPQ

3.2 Drive And Control System

(1) Traction machine. The implementation of Mitsubishi's PM gearless traction machine has resulted in a highly efficient system with high levels of ride comfort and quietness. For optimizing the compact design of that machine, the sheave, motor and brakes are arranged on the same rotary axis, in which 2 sets of double brakes are used.

(2) Control of the PM synchronous Motor. Highly accurate and fast response torque control can be achieved with the PM motor, by controlling the armature current so that the field flux intersects according to the pole position detector. Furthermore, an exciting current is not required, so the efficiency is high.

The speed control circuit of the drive control system for the PM motor uses the encoder's pulse signals as its feedback signal, and the current control circuit uses the armature current and pole position for feedback. For the current control circuit, a custom 300.000 gate LSI (large scale integration) chip, which has already been incorporated in Mitsubishi traction elevator system, has been adopted. This allows substantial increase in processing frequency and supports highly accurate, digital, current control.

For the inverter's main circuit, an IPM (Intelligent Power Module), containing 7 high-speed and low-loss switching element IGBT's (Insulated Gate Bipolar Transistor), is used and the control frequency of the PWM (Pulse Width Modulation) is raised to a frequency of 10 kHz. Through creating a quieter control system, the bothersome magnetic noise generated from the PM motor is reduced.

Figure 4 shows the armature current, speed and acceleration waveforms, of an elevator traveling upward with a full load at a speed of 60m/min. By adopting the gear-less traction machine and advanced motor control technology, within the GPQ system, a smooth ride comfort, equivalent to that of a high-speed elevator, is realized.

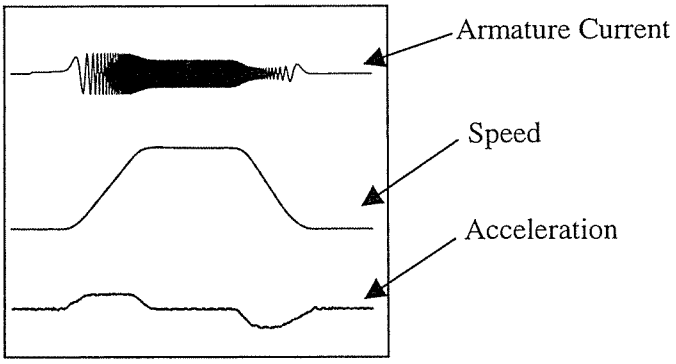

Figure 4: The waveforms of the GPQ

(3) Control panel. The control panel is split up in a main control panel and a sub control panel. Due to the limited space available between the hoist way wall and car, a new slim type of control panel was developed with a thickness of 87mm and a width of 340mm. It is suspended to a rope pulley mechanism with counterbalance in order to lower it in case of maintenance. During normal service the control panel is lifted to a higher level in order to prevent damage by water.
A contact on the control panel door prevents electrical operation if it is not closed.

For achieving a dramatic reduction of the outer dimensions of the control panel the power supplies were unified to one low voltage DC standard and a conventional transformer has been eliminated. Furthermore the thickness of the inverter unit has been reduced by using the recently developed thin cooling pipe.

3.3 Safety Provisions

In order to fully satisfy the maintenance and testing safety requirements of the Liftsdirective, a number of provisions were developed for the GPQ elevator.

(1) Pit safety system. – Due to the increase in maintenance that will take place in the pit, the number of potential risks to both maintenance personnel and passers-by has also increased. Mitsubishi developed a pit safety system that prevents these newly introduced risks, and thus ensures the same level of safety as required by EN81-1. As soon as a maintenance person enters the pit, that system will be activated. It means that, by opening the lowest landing doors with the emergency unlocking device, it is ensured that:

- All control operations are cut-off, except inspection operation calls from the pit. This prevents the risk that of unexpected operation during maintenance.
- The car unit is prevented from encroaching into the free maintenance height of 2 meters. This prevents the risk that the inattentive maintenance personnel may be hit by the car unit, even though under their control.
- A pit maintenance light is automatically switched on, thus preventing damage to the maintenance personnel's eyes and any mis-judgements due to poor lighting. The pit maintenance lights should not be mixed up with the regular shaft light, which can be switched on separately according EN81-1.

The pit safety system remains activated until it is reset by means of the reset button provided in the hall inspection panel. This resetting can only be done if all the doors are in the closed position.

(2) Hall inspection panel – at the lowest landing floor, a hall inspection panel is provided which can be used during the rescue of passengers trapped in the car, and for performing a number of dynamic tests from outside the shaft. The hall panel, which is locked by a unique key, has the following functions:

a) ***The hall operation device*** – this unit contains an auto/manual toggle switch, an emergency drive switch, up and down buttons and a 'hold to run' button. The emergency drive switch allows the controlled movement of the car unit at inspection speed, whilst by-passing the safety controls that are described in EN81-1. The hall operation device also contains a switch for disconnecting power to the elevator doors.
b) ***The reset button*** – this button has a double function; i) resetting the elevator system after exiting from the pit and ii) resetting the governor after being tripped.
c) ***The remote MCB button*** – this button allows for the switching off of the MCB (main circuit breaker) from outside the pit. Given that the MCB is positioned inside the pit, next to the entrance, if the car unit is blocking access to the pit then the remote MCB button can be used as required. Resetting the MCB can only be done from inside the pit, not by remote.
d) ***Inspection window*** – provides aforementioned line of sight of the indicator rope. A special light, on battery power, can switch on by the EMR light switch..
e) ***The remote governor tripping device*** – provided in accordance with EN81-1, in order to test the operation of the safety gear.
f) ***The brake release mechanism*** - By means of this device the brakes can be released from outside the shaft. As a result the gearless machine will then easily allow the car to move under gravity, which might be needed in case of rescuing people from the car if electric operation is impossible. The brake release lever is a separate part, which is stored inside the hall inspection panel. Releasing the brakes thus requires inserting that lever into the mechanism. Furthermore the mechanism is blocked by a safety pin. When releasing the brakes a LED indicator helps positioning the car within the door unlocking zone.
g) ***LED indicators*** – The LED indicators provide various information needed for trouble shouting and testing, such as power supply and a car being in the door unlocking zone.

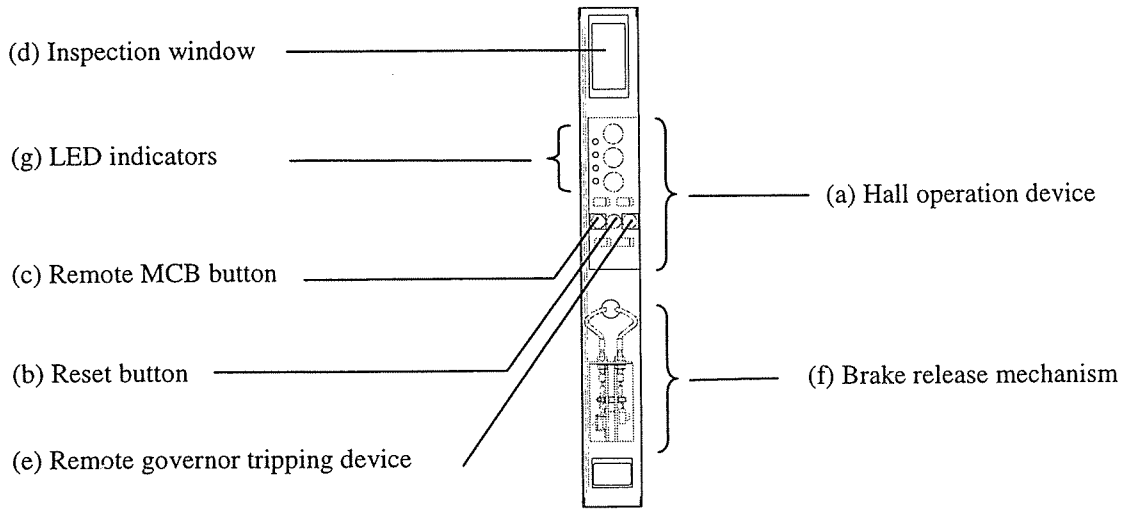

Figure 5: the contents of the Hall inspection panel

(3) Other special GPQ provisions

a) In the shaft:

- ***Pit operation device*** – during pit maintenance, the pit safety system exclusively allows the car to be moved through the pit operation device, as long as the car remains above a 2 meter free maintenance height. By pressing the 'hold to run' and down buttons simultaneously, the car unit can be lowered into the free maintenance height. This conscious act allows for maintenance to the lower aspects of the car unit.
- ***Countermeasures for water in the pit*** – as previously mentioned, the control panel can be lifted to a safe height with regard to water entering the pit. In addition, the GPQ is provided with a switch that interrupts the current to the traction machine and brake system if the water in the pit exceeds a certain depth. The traction machine is protected by a waterproof cover.
- ***Circuit breakers*** – As a result of the pit being an alternative machine room it is provided with a both a main circuit breaker and a Lighting circuit breaker. Located just above the pit ladder, both are easily reached from the lowest landing through the opened landing doors.

b) On the hall:
Hall indicator display – the hall indicator normally only displays the position of the car. In case of the GPQ, this unit can be switched to display inspection or test data temporarily.

c) In the car:
Car Operation Panel – behind the car operation panel, there are a series of switches which allow for temporary settings during inspection and testing.

4 CE MARKING

EC-type certification - The GPQ had undergone an EC-type investigation, according to Liftsdirective Annex V (module B), as executed by NIVL, the notified Dutch body. A Technical Construction File was compiled and submitted to the NIVL and a 630-kg lift with 4 stops and telescopic doors was erected and examined, as a model lift. The purpose of choosing this small lift was to be able of assessing the risks relating to limited free spaces in the pit.

Risk analysis - Due to the deviations from EN81-1 a risk analysis was drawn up. Risks were identified with the help of a risk identification checklist describing procedures and events step by step, including the condition of the lift, and giving insight in the cause and circumstances of the risks. Relevant risks were selected from that list and assessed and evaluated in the risk assessment list– the layout of which was a combination of formats proposed by two relevant standards.

Lift owner documentation - Each GPQ elevator system is be provided with the required lift documentation. Mitsubishi prepared GPQ-specific document parts, and included them within each copy of the TCF. For example, the instruction manual is written specifically for the GPQ, and contains warnings and instructions addressed to both the lift owner and competent persons (if present), and to skilled maintenance persons, in separate chapters.

5 CONCLUSION

Mitsubishi successfully developed an elevator for the European market that allows more freedom to the building design by leaving out the conventional machine. The GPQ provides high levels of performance and quality that are comparable with the levels of high-speed elevators. At the same time, the GPQ maintains safety levels that are demanded in the European Liftsdirective and laid down in the new EN81-1. As a result of this, the GPQ achieved EC-type certification and displays the CE-mark, as required.

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BIOGRAPHICAL DETAILS

Wim Offerhaus received his university degree of Industrial Design Engineering in 1993. After working as a mechanical engineer for another company he joined Mitsubishi Elevator Europe R&D Centre in 1997. He was closely involved in the certification and development of the GPQ.

Lidewij van Wagensveld received her college degree of Mechanical Engineering in 1990 and her university degree of Mechanical Engineering in January 1994. After working as a consultant for two companies she joined Mitsubishi Elevator Europe R&D Centre in 1997. She was closely involved in the development of the GPQ and the risk assessment.

Wouter Kempes received his university degree of Mechanical Engineering in 1994. After working as a mechanical engineer for another company he joined Mitsubishi Elevator Europe R&D Centre in 1997. He was involved in the certification and development of the GPQ.

Takenobu Honda joined Mitsubishi Electric Corporation in 1974. As a mechanical engineer at the development department of Inazawa works he was closely involved in the development of the mechanical drive system of the GPQ.