Five years ago, ThyssenKrupp Aufzüge introduced its machine-room-less (MRL) unit, Evolution®. The product and concept has been received in the market and spawned an entire range of special-application units. The classic unit comes in two options with standard dimensions for rated loads of 630kg and a capacity of eight passengers or 1000kg with a 13-passenger load with or without an additional opposite entrance. These units come with speeds up to 1.6mps and can travel up to 50 meters.

The flexible unit can be adjusted to handle rated loads up to 1800kg with a capacity of 24 passengers with or without the additional opposite entrance. Speeds up to 2.0mps and travel heights of 60 meters are possible (Figure 1). The exterior unit was designed as an add-on installation. The elevator comes with a rated load of 450kg and is pre-installed in a glass shaft framework which can be added to a building's exterior. The traffic unit works well in high-traffic areas, such as train stations or underpasses. This glass elevator is equipped with vandal-resistant features and has disability-friendly options, including voice announcements.

The newest and youngest member of the group is the compact unit which requires a shaft recess of only 300 millimeters (Figures 2 and 3). This option is excellent for special construction problems, such as rocky terrain. The bottom landing door is monitored electronically with a buffer support in the shaft recess for maintenance work. A collapsible apron is located underneath the car door and can be mechanically folded up during normal operation and folded out during a power outage or a malfunction of the elevator. It safely covers the gap between the car floor and building floor in the event of passenger rescue.

All of the Evolution MRLs are equipped with the Thyssen Mini gearless® drive.
EDUCATIONAL FOCUS: MACHINE-ROOM-LESS ELEVATORS

ELEVATOR KIT WITH SELF-PROPELLED CAB
by Theodor Helmle

Elevators without a separate machine room were introduced to the market in the mid-1990s and, since that time, the industry has presented a wide variety of derivative concepts. The motivating factor behind most of the associated development work was to circumvent patents already in force. Often this “circuitous route” resulted in solutions that rendered elevator installation and maintenance more difficult. Thus the costs that were saved at the machine room were shifted to the elevator installation firm. Manufacturers were even willing to forego proven suspension means such as steel wire ropes in the interest of devising novel solutions. But how can one engineer a lift that satisfies the architect’s vision – a lift without a machine room – and the elevator installer’s wishes – ease and safety in maintenance?

These considerations culminated in the development of the Apollo/ECD concept presented here. Analogies drawn from horizontal passenger transportation, i.e., automotive engineering, are used to explain certain details.

A motor vehicle is a ready-to-drive unit that leaves the assembly plant fully operational. The drive train and the control electronics are joined with the passenger compartment in a very limited and closely defined space. Insulation against noise and vibration enhances the ride quality. An attempt was made to identify parallel solutions for vertical passenger transport in an elevator cab. The cab rests on a frame that serves as a platform and is moved through the hoistway along the guide rails. If the drive unit is integrated into that frame, then its rubber mounts isolate the cab from vibrations generated at the drive and the guide rollers. All the drive technology, including the controls, should also be mounted on this frame, ready for immediate use. This makes it possible to traverse the shaft when the doors are being installed. Moreover, the wiring otherwise needed between the controls, frequency inverter and drive motor can be eliminated.

A further goal in the development of the machine-room-less (MRL) Apollo/ECD lift was to put a new system on the market, which, as a patented design, does not infringe on any existing patents. On the other hand, it draws upon components that have proven themselves throughout many years of service and thus are deemed to be absolutely reliable.

Moreover, the planner and elevator installer were to have available a concept that imposes no constraints in regard to the positioning of the machinery inside the hoistway and the location of the temporary machine room. Positioning the drive and frequency converter (with the integrated hoistway controls) at the cab eliminates any influence on hoistway dimensions. In addition, the installation point for a connection box (with the circuit breakers, computer interface and manual controls) and thus the siting of the temporary machine room can be selected at will. To satisfy today’s high expectations in regard to noise, efficiency and torque reserves, a highly dynamic, synchronous servo drive was selected for the Apollo/ECD lift.
In the interest of simplifying and speeding assembly, all the drive-train components – including the motor and frequency converter with integrated hoistway control – are matched precisely one with another so as to form an integrated, harmonized unit. This in turn makes it possible to use plug-type terminators at the traveling cables and at all other cable connectors.

**Advantages**
- Mounting the drive motor inside the hoistway is eliminated since the motor is delivered pre-installed at the crosshead.
- Smallest possible hoistway dimensions, thanks to mounting the entire drive system, including the servo drive and frequency inverter with its integrated control circuitry, on top of the cab.
- Positioning the temporary machine room as desired, at the head or the foot of the shaft or at any desired floor.
- EMC problems are solved because the frequency inverter with its integrated controls is fully enclosed in a metal housing, and the cables between the frequency converter and servo drive are extremely short.

**Highlights in the Electronics**
- Frequency converter and controls are merged into a single unit: Integration for optimized communications between control and regulation circuitry, matched precisely to the servo drive.
- Decentralized control technology: Parameters are assigned for the entire system (control and regulation circuits) using a single on-screen menu. Serial communications bus to the individual stations. The programming unit can be connected at the top of the cab, inside the cab or at the switchgear cabinet.

- Digital hoistway selector: The digital selector design, doing away with the need for additional incremental transducers along the hoistway, brings about a considerable reduction in assembly time.
- Fully automated calibration trips: This trip, made to collect hoistway data, is carried out using the programming unit – at the push of a button, so to speak.
- Automatic travel curve optimization: Achieved through ideal specification of travel speeds and the acceleration and deceleration phases, in dependency on the distance to be covered. This makes it possible to achieve the shortest floor-to-floor travel times.

**Characteristics**

**Shortening Installation Times**
Since assembly work is always costly, the market success of a new concept will depend to a great degree upon the extent to which assembly time can be reduced. This concept eliminates assembling and wiring for the frequency converter and integrated hoistway control unit. The controls are pre-mounted on the crosshead. All the other cable connections are made with plugs and sockets. In addition, as was mentioned at the outset, the only components employed in the Apollo/ECD are those which have fully proven their capacities through years of use. Moreover, the assembly loads and their positioning in the hoistway have a critical influence on assembly times.

The Apollo/ECD lift offers significant advantages in many respects. On the one hand, there is the servo drive, which develops a maximum acceleration moment of 1500Nm with a total weight of just 135 kilograms (including the drive sheave). On the other hand, this drive is conveniently mounted at the crosshead and not at a poorly accessible point in the hoistway, such as directly beneath the shaft ceiling.
EDUCATIONAL FOCUS: MACHINE-ROOM-LESS ELEVATORS

The advantage of easy assembly is augmented by the fact that the motor need not be aligned since – by virtue of its being bolted to the cab frame – it is positively centered on the rails. The traveling cables are pre-assembled at the factory for immediate use and are easily installed using plugs which are keyed to prevent incorrect connection. Using components, which are always the same and which are exactly matched one to another, opens the door to using motor commutation to implement a digital selector. This is attractive due to its simplicity in assembly and commissioning, which can be done by a single technician in a brief period of time.

Emergency Rescue

Rescuing trapped passengers must always be given special attention when designing MRLs. The Apollo/ECD lift offers several options to meet customer desires and local conditions. Basically, the lift can be moved in the inching mode, under reserve battery power, in the direction of the greater load (cab or counterweight) by using a push button to override the braking switch located in the switchgear cabinet. A leveling sensor indicates that the cab has reached a landing.

Various options are available to augment this basic version. A mechanical variation is an additional Bowden cable used to release the brakes mechanically; it is located behind the cab control panel. With this, passengers could also be given access to the brake release; the brakes would then automatically re-engage when the cab reached a landing, this being triggered with a mechanical actuator. The elevator can be run automatically and electrically, at 48VDC, with a supplementary, battery-buffered auxiliary controller. This feature is activated by a phase-monitoring device in response to a power failure. The supplementary controller attempts to move the cab in a default direction. If the moment developed using the back-up battery and specified by the auxiliary controller is insufficient to do the job, then the cab will automatically be moved in the opposite direction, powered by an auxiliary generator. The system will in all events be shut down by the leveling signal at the nearest landing.

Energy Use

In contrast to legal requirements or patent law, all the rules and laws of physics apply equally to everyone. Thus, it is not physically possible to move a cab weighing 630 kilograms at 1.0mps with only 3.2kW of rated power. According to the laws of physics, a system such as this would have an overall efficiency level of nearly one. Seen more seriously, there are essentially two opposing approaches to generating a moment. One option is to use gearing featuring a high step-down ratio in conjunction with a high-speed motor developing low-rated torque; the other is a gearless direct drive with high torque and low speed. The formula $P = M \omega$ applies in both cases, and the product of moment $x$ distance is the same.

When comparing this system with direct drives, geared motors are distinguished by their smaller size and lower copper losses. The reason is found in the limited rotational thrust (tangential force) of electrical motors. Due to the high torque levels needed in elevator drives, exceeding 1000Nm, direct drives cannot be compact, nor can a lightweight design be used in their manufacture. The advantages of direct drives can be exploited only where higher travel speeds are specified. In most cases (up to about 2mps rated speed), optimized helical gearing and drive motors with dynamically balanced rotors are of equivalent quality and operational utility but represent the more compact and more economical solution. The great copper losses in direct drives have to be added to the drive power, and this will have to be taken into account when selecting the frequency inverter.

A further disadvantage of gearless drives results from the rules applicable to elevator technology. Every drive has to brake mechanically when it is at rest, and the brakes have to be held open electrically during the entire trip. A redundant, dual-circuit brake system is prescribed here. Moreover, the brakes have to be dimensioned so that either of the brake circuits is able to stop and hold the lift securely. In gearless direct drives the unavoidable result is a very large brake system since it has to counteract all the moment present at the drive sheave. The effects of this disadvantage are even more acute in the 1:1 gearless applications now coming into use. The brakes’ power consumption (when released) is proportional to the braking force.

In drives utilizing gearing, the brakes are downline from the gearbox. The braking moment to be applied is reduced by the step-down gearing, resulting in a smaller system with lower power consumption.

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Marketing

The Apollo lift is being marketed in Germany by Leistritz in the form of a complete construction kit. Distribution in the remainder of Europe is in the hands of the Kleemann Co., while the Edinburgh Co. is responsible for Asia.

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