Proceedings

The 7th Greater Pearl River Delta Conference on
Building Operation and Maintenance

SMART Facilities Operation and Maintenance

6 December 2016

Chiang Chen Studio Theatre
The Hong Kong Polytechnic University

Analysis of standby power consumption for lifts and escalators

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Abstract

Lifts and escalators are very important for urban cities like Hong Kong, for the operation and functioning of high-rise buildings and other facilities. These transportation systems constitute a significant part of the electrical power demand and energy consumption in buildings. However, the information about their energy performance and energy saving measures are limited. Very often, the energy is wasted during the idle and standby situations. This research aims to study the principle and characteristics of standby power for lifts and escalators so as to evaluate possible measures to control and reduce the standby power consumption. Relevant research and technical standards have been studied to identify useful information for assessing the standby power. Field measurements have been carried out in 21 units of lifts and 14 units of escalators in Hong Kong to examine the standby characteristics and energy consumption. It is found that the standby power consumption is affected by traffic demand, operation characteristics, control methods and drive technology. To reduce the standby energy use, it is essential to control non-critical components (such as air-conditioning and lighting). Good potential for energy saving can also be found in motor drive technology and smart controls.

Keywords

Lifts and escalators; standby power; energy consumption; Hong Kong.

1 Introduction

Lifts and escalators are also known as vertical transportation systems in buildings (CIBSE, 2015) and they constitute an important part in total energy consumption of modern high-rise buildings (So and Li, 2000). For urban cities like Hong Kong, lifts and escalators are very important for the operation and functioning of high-rise buildings and other facilities such as subway stations, airport terminals and shopping malls (EMSD, 2007). These systems constitute a significant part of the electrical power demand and energy consumption in buildings (ISR-University of Coimbra, 2010). However, the information about their energy performance and suitable measures to reduce energy wastage are limited (De Almeida, *et al.*, 2012). Very often, the energy is wasted during the idle and standby situations or when the lifts and escalators are lightly loaded (Frazier, 1999; Uimonen, *et al.*, 2016).

In recent years, energy efficiency of lifts and escalators has attracted more and more attention in the world as many countries are developing policies and programmes to control energy use of vertical transportation to enhance energy conservation in buildings (De Almeida, *et al.*, 2012; Sachs, 2005; Sachs, Misuriello and Kwatra, 2015). However, the lack of detailed information about the pattern and usage of energy consumption in vertical transportation has hindered the strategy to achieve effective energy saving for these systems. At present, some research studies and methods have been developed for assessing the energy consumption of lifts and escalators during normal running mode (Al-Sharif, 2004 & 1998; Carrillo, *et al.*, 2013). But the effect of standby power consumption, which often occupies more time than the running mode, has not been fully understood and evaluated.

This research aims to study the principle and characteristics of standby power for lifts and escalators so as to evaluate possible measures to control and reduce the standby power consumption. Relevant research and technical standards from other countries (such as Germany, UK and USA) have been studied to identify useful information and theories for defining and assessing the standby power. Field measurements have been carried out in 21 units of lifts and 14 units of escalators in Hong Kong to examine the standby characteristics and energy consumption. It is believed that the standby phases offer particularly high potential for cost-effective energy savings.

2 Energy consumption of lifts and escalators

Nowadays, lifts and escalators are used commonly for different purposes: convenience of occupants, barrier-free access in a building, serving high-rise structures, and moving heavy loads in industry and businesses. They can account for a significant percentage of energy consumption in buildings. CIBSE (2015) indicates that vertical transportation constitutes 3-8% of the overall building energy consumption. For urban cities with many tall buildings, it will contribute a significant portion of the electricity use and peak demand. For example, it is estimated that there are more than 62,000 lift units and 8,700 escalators in Hong Kong (EnB, 2015); they contribute 7%-15% of electricity use in commercial and residential buildings. It is very important to promote energy efficiency for these installations (EMSD, 2007).

2.1 Energy saving potential

In Europe, the E4 Project (short for “Energy Efficient Elevators and Escalators”, http://ec.europa.eu/energy/intelligent/projects/en/projects/e4) was carried out in recent years to analyse the energy efficiency potentials and policy measures for lifts and escalators (ISR-University of Coimbra, 2010). The results indicate that considerable technical efficiency potentials exist for lifts (more than 60%) and escalators (around 30%). However, various market barriers prevent the diffusion of these energy-efficient technologies and measures (De Almeida, *et al.*, 2012).

In fact, the amount of power at normal running mode and standby mode is basically independent with each other. That means low frequency of use does not imply low consumption during standby mode. A research project in Switzerland (Nipkow, 2005) with 33 lift units found that the standby energy accounted for 25% to 80% of the total lift energy consumption. Another project in Europe determined that standby consumption of lifts and escalators could represent up to 95% of total energy consumed of the installations (De Almeida, *et al.*, 2012). The research findings clearly indicated that the standby demand is a significant factor in the overall consumption and is greatly influenced by the usage pattern. With low frequency of use and high standby usage ratio, more than 65% of energy use could be saved by reducing the standby consumption in lifts and escalators.

2.2 Principle of energy analysis

In general, the energy inefficiencies of lifts and escalators can come from direct and indirect causes. Direct causes are equipment oriented, which depends on how energy-efficient of the component used, while indirect causes are operation oriented, which depends on the user behaviour and traffic management (ISR-University of Coimbra, 2010). The energy efficiency in lift and escalator systems can be assessed and optimized by studying the performance of these two aspects. Figure 1 shows the major factors affecting the energy consumption of lifts.

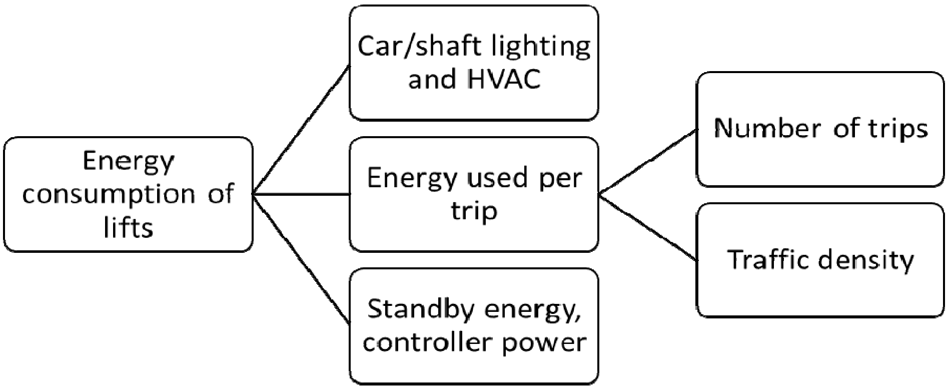

Figure 1 - Major factors affecting the energy consumption of lifts

For most lift and escalator installations, the electricity supply is separated into two feeders: the main power and the ancillary power. Table 1 shows the typical items for them and other related equipment. The main power is connected to the controller, motor drive, converter and brake, doors, critical lighting and direction indicator. The ancillary power is supporting the equipment such as lighting, ventilation fans, cooling and heating, alarm devices, CCTV, displays, consoles and emergency battery supplies. It is believed that the ancillary equipment is the main issue affecting the standby power.

Table 1 - Main power, ancillary power and other equipment

For lifts:	
Main power	Controller, motor, converter and brake, doors
Ancillary power	Car light, ventilation fan on car, alarm device and tele-monitoring, emergency power supply (battery)
Other equipment	Hoistway light, machine room light and ventilation
For escalators or moving walks:	
Main power	Controller, motor, converter and brake, step gap lighting, comb plate lighting, direction indicator
Ancillary power	Lightings (balustrade, etc.), remote alarm and monitoring
Other equipment	External machine room light and ventilation

* Information adapted from ISO (2012).

To assess the energy consumption in lifts, five different methods can be used (Al-Sharif, 2004): (a) measurements, (b) calculations from first principle, (c) calculations using tables and rule of thumb, (d) combinations of measurement and calculations, and (e) computer modelling and simulation. For escalators, as they run continuously regardless of passenger demand, they consume a fixed amount of energy if not boarded by passengers (Al-Shariff, 1998). In order to assess the energy use of an escalator, it is necessary to evaluate its behaviour in terms of traffic such as people per hour, loaded and unloaded periods of time, and so on (Carrillo, *et al.*, 2013). The service performance, intensity and passenger load depend on building type, purpose and population (Markos and Dentsoras, 2016).

2.3 Technical standards

Two sets of technical standards are widely used in the world for the energy efficiency assessment of lifts and escalators. They are VDI 4707 (VDI, 2009, 2013 & 2016) and ISO 25745 (ISO, 2015a, 2015b & 2012) which are broadly similar in structure. VDI 4707 is a voluntary guideline established by the German Association of Engineers (Verein Deutscher Ingenieure, VDI) for evaluating the energy efficiency of lifts. This guideline was created with the aim of enabling easy calculation of the typical energy demands of a lift installation depending on its use. The total energy demand shall be the summation of travel demand and standby demand. It defines an energy label with the energy efficiency class of the lift (A to G) and provides a figure for a yearly nominal energy demand (kWh per year).

ISO 25745 sets down standard procedures to be used when making energy measurements and checking energy conformance. The standard provides a consistent method of measuring actual energy usage of an installed lift, escalator and moving walk. It also offers a simple method to periodically verify that energy usage of an installed unit (existing or modernized) has not changed. The standard considers all escalators and inclined moving walks up to a rise of 8 m and horizontal moving walks with a length up to 60 m (this represents about 85 % of worldwide installed units). In ISO 25745, the concept of standby mode is well-defined and divided into 3 parts. Usage pattern is deeply considered to determine the ratios of time spent in standby mode. Analysis of standby mode is more specific than VDI 4707 in terms of period and components.

3 Standby power consumption

In general, the normal operation of vertical transportation is divided into two parts: running and standby. For most building types, lifts and escalators are idle far more than they are moving. It is found that the average standby period is three times higher than the average travel time for vertical transportation (De Almeida, *et al.*, 2012). For lifts with relatively low frequency of use (such as in residential buildings), the proportion of total energy use attributed to standby situation can amount to more than 75% (Nipkow, 2005; Sachs, 2005). As standby power components are usually not inherent to the core functions in the mechanical and electrical aspects of vertical transportation, reducing standby power should be fairly easy to implement and can be very cost effective.

3.1 Definitions of conditions

To evaluate the standby power of lifts and escalators, it is fundamentally crucial to understand the different conditions of operation. Table 2 shows the basic definitions of idle, standby and load conditions for lifts, escalators and moving walks. For testing of lifts, a reference cycle is applied to represent the running mode. It is the cycle during which the empty car is run from the bottom terminal landing, to the top terminal landing, and then back to the bottom terminal landing including two complete door cycles (ISO, 2015b). After the cycle running, the lift will be allowed to “rest” for a while (say, five, ten or thirty minutes) at the lowest landing. An energy measurement will then be made with the lift maintained at the lowest landing; this will give the standby energy consumed. According to ISO (2015b) and VDI (2016), energy consumption of standby mode shall be counted from idle condition. Therefore, the idle condition shall also be a part of standby mode.

Table 2 - Definitions of idle, standby and load conditions

For lifts:	
Idle condition	condition when a lift is stationary at a floor following a run before the standby mode is entered
Standby condition	condition when a lift is stationary at a floor and may have reduced the power consumption to a lower level set for that particular lift
For escalators or moving walks:	
Load condition	condition in which an escalator or moving walk is running with one or more passengers
No load condition	condition when an escalator or moving walk is running at nominal speed without passengers
Standby condition	condition when an escalator or moving walk is stationary and powered on and can be started by authorized personnel

* Information extracted from ISO (2015a & 2015b).

3.2 Standby modes of escalators and moving walks

The standby condition for escalators and moving walks as shown in Table 2 refers only to a stationary situation with authorized manual starting. According to ISO (2015a), the standby situation of escalators and moving walks consists of three modes:

a) *Automatic Low-Speed Standby*: The condition when an escalator or moving walk is running at slow speed without passengers. Consumption in this mode is usually close to half of the consumption during the normal operating mode.

b) *Automatic Stop Standby*: The condition when an escalator or moving walk is stationary and powered on and can be resumed by passenger walking through. Usually electricity consumption is at its lowest during stopping.

c) *Manual Stop Standby*: The condition when an escalator or moving walk is stationary and powered on and can be started by authorized person. Power is needed in stop-standby modes because the lighting, sensors, drives and control panel still consume energy.

Very often, automatic low-speed mode and automatic stop mode are mutually exclusive in one escalator or moving walk. That means the escalators or moving walks usually only have single energy saving feature in standby mode. In general, the standby mode will be activated when there is no passenger detected for a certain time by sensors built near the entry of the escalator or moving walk (Uimonen, 2015). The time depends on the settings by the manufacturer, building designer or building manager. In case the escalator or moving walk is stopped automatically after low speed mode is operated for a certain amount of time, standby consumption is considered to be the summation of the consumption for automatic low-speed, automatic stop and manual stop modes (Uimonen, *et al.*, 2016).

3.3 Components of standby power consumption

As shown in Table 1, the electricity consumption of lifts and escalators is related to the main power and ancillary power. The components of standby power and energy consumption will vary depending on the system design and associated ancillary equipment. For example, Nipkow (2005) has identified two major factors that can cause unnecessarily high standby consumption in lifts, namely, continuously running cabin lights and door locking devices. He also found that lift control device and frequency converter may be significant in the standby consumption. Other components such as floor display and operating consoles (in each floor and inside the lift car) have relatively small influence. However, if other equipment and devices such as air-conditioner and display screens (for weather and advertisements) are installed, they will contribute to the standby consumption.

For escalators and moving walks, it is believed that the ancillary power for balustrade lightings, remote alarm and monitoring are usually small compared with the main power. Hence, the major components of the standby consumption are related to the items of the main power. As described in the previous sub-section, the standby consumption is the combined effect of automatic low-speed, automatic stop and manual stop modes. Therefore, the control and operation methods, electrical and mechanical design, as well as passenger characteristics must be considered when assessing the standby performance (Uimonen, 2015).

4 Field measurements

Field measurements and evaluation according to ISO 25745 have been carried out in 21 units of lifts and 14 units of escalators in Hong Kong to examine the standby characteristics and energy consumption. A calibrated Hioki PW3198 Power Quality Analyzer and related electrical instruments were used to measure the main power and ancillary power. For lifts, the daily standby (non-running) energy consumption was determined from the summation of energy use in the idle, 5-min standby and 30-min standby periods. The idle power, 5-min standby power and 30-min standby power were measured using the instruments on an average basis. The time ratios of each non-running mode were determined from ISO 25745 based on the usage category. Therefore, Annual standby energy (kWh) = Non-running time (Hour) x 100 x [Idle power (W) x Idle time ratio + 5-min standby power (W) x 5-min standby time ratio + 30-min standby power (W) x 30-min standby time ratio].

To investigate the influence of standby consumption for the technologies of recent years, all selected units were installed within 5 years. The selected units are from commercial and residential buildings, schools, railway stations, industrial buildings and shopping malls. Table 3 shows the details of the lift units and Table 4 shows the details of the escalator units. The energy consumption model and usage categories in ISO (2012) were used to estimate the annual standby and running energy consumption. Then the annual standby-running (annual S/R) ratio was calculated for each unit by dividing the annual standby energy (kWh) by the annual running energy (kWh).

4.1 Analysis of the lift units

Figure 2 indicates the annual running and standby energy consumption of the 21 lift units. It is clear that standby consumption is a very important issue and it represents 10.4% to 98.5% of the total lift electricity consumption. The most important factor affecting the annual S/R ratio for the lifts is the number of trips per day. As shown in Table 3, the annual S/R ratio range from 0.12 to 30.97. In general, the higher the number of trips per year assumed for the usage category, the lower the annual S/R ratio will be. Some variations of the annual S/R ratio may come from the lift specification such as rated speed and rated load.

The idle power of the 21 lift units varies from 208 W to 2576.9 W. These variances can be explained by the fact that high power consuming equipment such as air-conditioner is installed in some lift units. If a lift does not have air-conditioner, typically, the idle power is around 200 W to 500 W only. After idle condition, the lift will enter into standby condition and the energy saving features will bring down the standby power significantly. The power reduction from idle condition to 5-minute standby condition is much larger than that from 5-minute to 30-minute standby condition. It is because during standby modes the energy is mainly consumed in control panel of motor drive. The control panel must be in “ON” state in order to transmit the signals and make decisions to maintain the lift in a safe condition and ready for turning on the slept equipment. It is found that the lift units with higher vertical rise and rated speed have larger power consumption during these standby periods.

Table 3 - Details of the lift units selected for field measurements

Lift Ref. No.	Building Type	Vertical Rise (m)	No. of Floor	Rated Load (kg)	Rated Speed (m/s)	Idle Power (W)	Standby Power in 5 min. (W)	Standby Power in 30 min. (W)	Annual Standby Energy (kWh)	Annual Running Energy (kWh)	Annual S/R Ratio
L1	Commercial	28.3	8	1600	1.6	394.0	246.1	157.5	2747	268	10.25
L2	Industrial	10.2	3	8200	0.5	2390.8	139.8	89.5	3597	2611	1.38
L3	Residential	7.0	3	750	1.0	1318.0	127.9	95.9	2358	299	7.88
L4	School	9.6	4	1800	1.0	1413.2	211.5	152.2	2447	79	30.97
L5	Industrial	4.6	2	4000	1.0	2438.5	117.8	81.3	5474	2310	2.37
L6	Industrial	4.6	2	630	1.0	1338.5	118.3	94.7	3322	591	5.62
L7	Railway	17.4	3	1800	1.0	341.4	167.7	119.1	7216	4078	1.77
L8	Commercial	13.5	3	1600	2.0	407.5	264.8	174.8	2301	1395	1.65
L9	Commercial	15.0	3	1800	1.0	278.0	158.5	112.5	1534	2014	0.76
L10	Commercial	12.1	3	1600	2.0	398.5	258.1	170.3	2254	4238	0.53
L11	Residential	11.0	2	900	1.6	1334.9	252.6	161.6	4859	2025	2.40
L12	Residential	152.8	46	900	3.5	2576.9	1288.5	811.7	13456	14740	0.91
L13	School	35.0	8	2000	1.8	1565.0	370.8	248.4	5914	7295	0.81
L14	Commercial	121.3	31	1800	3.0	2297.7	1122.5	684.7	11694	17012	0.69
L15	School	60.0	12	2000	1.8	1649.8	488.4	317.4	6311	15277	0.41
L16	Residential	60.3	13	1600	2.5	833.5	649.5	357.2	4496	4781	0.94
L17	Residential	13.3	6	1600	1.6	416.3	264.4	169.2	2220	5825	0.38
L18	Commercial	116.6	16	1600	3.5	2269.6	1091.1	741.9	10741	15326	0.70
L19	Railway	4.8	2	1000	1.0	424.2	118.7	84.3	1398	4394	0.32
L20	Commercial	5.1	2	1000	1.0	208.0	120.1	81.7	883	7631	0.12
L21	Residential	83.9	20	1600	4.0	2165.1	895.7	573.3	6107	20365	0.30

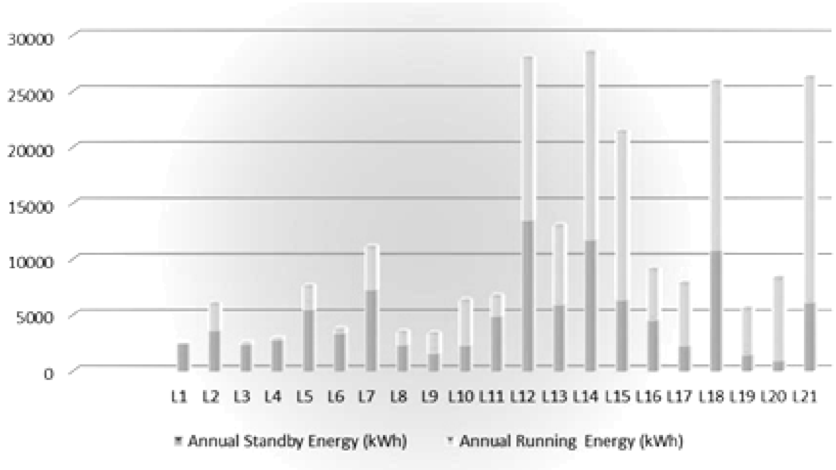

Figure 2 - Annual running and standby energy consumption of the lifts

Table 4 - Details of the escalator units selected for field measurements

Escalator Ref. No.	Building Type	Vertical Rise (m)	Escalator Inclination (degree)	Step Width (mm)	Motor Power (kW)	Rated Speed (m/s)	Direction	Automatic Standby Mode Feature	Annual S/R Ratio
E1	Commercial	5.0	30°	1000	8.0	0.5	Up	Start-Slow	0.31
E2	Commercial	5.0	30°	1000	8.0	0.5	Down	Start-Slow	0.34
E3	Commercial	4.7	35°	1000	7.5	0.5	Up	Start-Slow	0.39
E4	Commercial	4.7	35°	1000	7.5	0.5	Down	Start-Slow	0.45
E5	School	5.2	30°	1000	8.0	0.5	Up	Start-Stop	0.05
E6	School	5.2	30°	1000	8.0	0.5	Down	Start-Stop	0.05
E7	Shopping mall	5.0	30°	1000	8.0	0.5	Up	Start-Slow	0.35
E8	Shopping mall	5.0	30°	1000	8.0	0.5	Down	Start-Slow	0.38
E9	Commercial	7.1	30°	1000	15.0	0.65	Up	Start-Stop	0.28
E10	Commercial	7.1	30°	1000	15.0	0.65	Down	Start-Stop	0.3
E11	School	5.0	35°	1000	9.2	0.5	Up	Start-Slow	0.3
E12	School	5.0	35°	1000	9.2	0.5	Down	Start-Slow	0.31
E13	Railway	6.0	30°	1000	15.0	0.65	Up	N/A	N/A
E14	Railway	6.0	30°	1000	15.0	0.65	Down	N/A	N/A

4.2 Analysis of the escalator units

For escalators, it is noted that the travel and standby demand could not be found from the standards (Carrillo, *et al.*, 2013). Therefore, a method for counting of time spent of the running, standby and stopping was implemented and introduced. The power consumption was determined in different states of operation. They include measurements over a period of 5 minutes when running at nominal speed, in a stop mode and finally, if available, in a low-speed mode. To be safe, measurements were made for empty escalators only. To take passenger load into account as found in real systems, the annual consumption values were calculated by multiplying annual running consumption with a typical load factor. Then the annual standby-running ratio was calculated for each unit.

As shown in Table 4, the annual S/R ratios of the escalators are rather low (0.05 to 0.45). That means the standby period and related power consumption for these escalators are small. In most of the time, the escalators are either fully utilized or completely shut down. On the other hand, the annual S/R ratio of the escalators with start-slow feature is around 0.3 to 0.4 no matter what the technical specification of the escalator is. It is because the escalators were set to move at 0.4 times of the rated speed when the escalators were turned into standby mode. Small deviation may be found due to the consumption in ancillary power. For example, some balustrade lighting of the escalators would not be turned off even in the standby mode.

Moreover, it is found that the annual S/R ratio of the upwards escalators are typically lower than that of downwards escalators for the same condition because escalators would consume more energy during moving upwards.

5 Discussions

For comfort reasons (smooth acceleration, precision braking, etc.), modern lift drives are already equipped with highly efficient technologies, and these are now also available for hydraulic lifts, using energy storage. This means there are significant efficiency potentials in the area of drives and motors, especially when old systems are to be replaced (Sachs, Misuriello and Kwatra, 2015). Such a trend in lift modernization can help reduce standby consumption in existing buildings with old lift systems.

The electricity in standby mode is mainly consumed in lighting, ventilation, air-conditioner, buttons and signage. For lighting and signals, energy efficient LED devices are already very common in the market and have been used in many lift and escalator installations. At the same time, energy savings can be unlocked by smart and intelligent automatic control system. Standby solutions power down the ancillary equipment when it is not in use, providing substantial energy savings, especially in buildings with periods of low usage. For example, in-car smart sensors and software automatically switch to a "sleep mode," turning off lights, fans, music, and video screens when unoccupied (Kwon, Lee and Bahn, 2014).

Although standby power of lifts and escalators is small compared with running power, the influence of energy contribution should not be overlooked because the standby can be held for a long duration. Generally, the standby period will occur in the mid-night for most building types and the lifts are seldom switched off because some passengers may need to use them. On the other hand, the standby period will last longer during the weekend and holidays. For some buildings such as schools and universities, during holidays and semester breaks, the lifts and escalators are at very low usage and should better be shut off.

In order to promote energy conservation further, lifts and escalators are now covered in some building energy efficiency standards such as ASHRAE Standard 90.1 (Sachs, Misuriello and Kwatra, 2015). Table 5 shows the lift car efficiency requirements in ASHRAE Standard 90.1-2013. It specifies minimum efficiency levels for car lighting and ventilation and sets standby-mode requirements for them. This can enhance the awareness in the market and facilitate the development of relevant energy efficiency policies and technologies.

Table 5 - Lift car efficiency requirements in ASHRAE Standard 90.1-2013

Component	**Requirement**
Lighting	For the luminaires in each lift car, not including signals and displays, the sum of the lumens (lm) divided by the sum of the watts shall be no less than 35 lm/W.
Ventilation power limitation	Car ventilation fans for lifts without air conditioning shall not consume over 0.7 W per L/s at maximum speed.
Standby mode	When lift car is stopped and unoccupied with doors closed for over 15 minutes, car interior lighting and ventilation shall be de-energized until required for operation.

6 Conclusions

In the past, standby power of lifts and escalators was often overlooked because of its small amount compared with the running power. In fact, the research worldwide in recent years indicated that the duration of standby period is usually many times longer than the normal running period. As a result, the standby power/energy consumption can be as high as 95% of the overall consumption in vertical transportation.

The results of field measurements for 21 units of lifts in Hong Kong showed that standby consumption represents between 10.4% and 98.5% of the overall lift consumption. The field study for 14 units of escalators also indicated high potential for energy savings. The current research findings in Hong Kong are in line with the previous studies conducted in Europe and other countries. It is hoped that useful information and more knowledge on the energy performance of lift and escalator systems in urban cities and high-rise buildings can be gradually established.

It is found that the standby power consumption is affected by traffic demand, operation characteristics, control methods and drive technology. To reduce the standby energy use, it is essential to control or turn off non-critical components (such as air-conditioning, lighting) in lift car and escalator. Good potential for energy saving can also be found in motor drive technology and smart controls.

7 Acknowledgments

The authors would like to express sincere thanks to those people who were supporting the field measurements and providing useful information for the research.

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