

Towards low carbon lifts

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ABSTRACT

CIBSE Guide F suggests that lifts in buildings use between 5% and 15% of a building's energy consumption dependent on the building profile and lift technology employed. Part L of the Building Regulations calls for lower CO₂ emissions by requiring better building properties (thermal, air tightness, etc.) and lower consumption by the major energy users (HVAC, lighting, etc). It specifically excludes lift systems. Is this omission justified? As the other energy users reduce their consumption, the energy used by lifts will increase in percentage terms. Modern lift systems using variable-voltage, variable-frequency regenerative drives are highly efficient. But, of the UK stock of some 250,000 lifts, at least half are over 25 years old¹. This paper looks at five opportunities to make lift installations even more energy efficient.

1 INTRODUCTION

The Energy Performance of Buildings Directive (EPBD) challenges the UK to reduce energy consumption and hence CO₂ emissions and to make buildings more energy efficient. The UK approach is mainly centred on amending Approved Document L to the Building Regulations, a draft of which was published in July 2004 with the intention to enact it before the end of 2005. Part L concentrates on the air tightness and effective insulation of the building and the efficiency of HVAC and lighting plant. It does not appear to consider any other energy consuming equipment.

Part L specifically states “vertical transportation systems are not currently subject to the requirements of Part L.”. Why? It is difficult to understand this exclusion as the 250,000 lifts installed in the UK do consume substantial amounts of energy! Although modern lift systems employing variable-voltage, variable-frequency (VVVF) motor drive technology are very efficient there is still room for significant improvement particularly for the some 125,000 lifts in the UK that are over 25 years old.

If owners take notice of the need for energy efficiency (or are made to take notice by the requirement for energy certificates) then total energy consumption of a building will fall. The energy consumed by lifts will then become more noticeable. There are several possible measures that can be taken to reduce energy consumption and some are described below.

2 REDUCING THE ENERGY CONSUMED BY IDLE LIFTS

All lifts require car lighting. Some (optionally) have ventilation fans and other devices such as information panels, CCTV cameras and even HVAC systems. Energy reduction could be achieved by turning off the car lighting and any auxiliary equipment, when the lift is idle and unoccupied.

¹ See: BS5655-11: 2006, Figure 1 or BS5655-12, Figure 1 or CIBSE Guide D:2005 Figure 16.1.

How much time does a lift stand idle ? Assume in a typical office building that all lifts are 100% active from 8am to 6pm, 50% active from 6am to 8am and 6pm to 8pm and 0% active from 8pm to 6am. This is 12 hours of 100% inactivity per working day. Assume 250 working days per year and 105 non working days, when the lifts are 100% idle, then this gives 5,520 hours of lift idleness in a year of 8,760 hours.

Clause 8.17 of BS EN81-1/2: 1998 requires the car lighting to provide an intensity of 50 lux at floor level. For a small car with a rated load of 630 kg this could be provided by a 40 watt low energy lamp. Bigger cars would require more luminaires, (say) about 100 watts for a car with a rated load of 1600 kg. These are minimum levels and usually these are exceeded in offices in order to make lift car interiors “inviting” rather than “unappealing”. In public housing the lighting is likely to be at the minimum allowable values.

Suppose the lighting were turned off in all the UK’s 250,000 lifts after (say) 5-minutes of idleness and that the average lighting load was 100 watts. Then for the 5,520 idle hours there would be a saving on lighting of 138,000 MWh per year. This figure would be higher if the other auxiliary plant is also turned off.

For safety reasons the switching control for the car lighting would need to ensure that a passenger does not enter a dark car, or a car goes dark when passengers are present.

The motion of a lift, the door movements and the service of passenger landing and car calls are supervised by a lift controller. When a lift is idle these controllers consume energy in their standby mode. Measurements made on eight different lift installations indicated a range from 25 W to 2 kW. The energy consumption was dependant on the controller technology and age of the equipment. At the high end the consumption was often the result of powering an isolation transformer or of energising DC motor windings in standby mode.

As lifts can be idle for some 5,520 hours each year consideration could be given to switching off at least the isolation transformer and any pre-energising motor winding power, leaving on only the control electronics in standby mode. The switching mechanism should be of the thyristor/transistor “soft” type rather than a contactor/relay “hard” type, as this reduces surges and is kinder to the equipment. The saving per lift could be several times higher than the action of turning the lights off.

3 REDUCING THE NUMBER OF LIFTS IN SERVICE DURING OFF PEAK PERIODS

Barney (2003) describes the classical traffic demand for an office building, shown in Figure 1. Its origins are from the 1960s before flexitime regimes were introduced and personnel attendance was more disciplined. It serves, however, to illustrate the different peak demands in an office building. During the morning-incoming (uppeak) traffic there is a significant up demand. At the end of the day the evening-outgoing (down peak) traffic demand dominates. Today, possibly, the midday traffic is the most significant demand, as there are simultaneous up and down traffic demands, together with some interfloor traffic. Between the three peak demands, during the morning and afternoon periods, there is an interfloor traffic demand, which is much smaller than the other three peak traffic conditions.

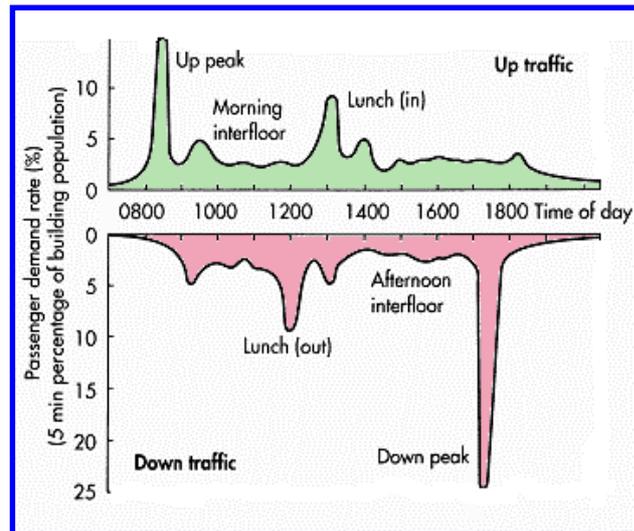


Figure 1: Classical traffic demand pattern for an office building

Whereas the three peak demands require the full capacity of a lift installation, interfloor traffic never fully utilises its underlying capability, as the demand is so much lower. For example, if each occupant of a building were to use a lift once during each morning and afternoon interfloor traffic period (each assumed to be about three hours) then the demand would represent 33% of the building population per hour, ie: about 3% per 5-minute period. This level of interfloor activity would be considered “busy”. This being so, do all lifts need to be in service during periods of low demand ?

Simulations (using the ELEVATE traffic simulation program) employing the standard benchmark templates (Peters, 2005) have been carried out for the four traffic conditions. Results are listed in Table 1 for two different lift installations. Passenger average waiting times (AWT) and passenger ninety percentile waiting times (90%), in seconds, are shown.

Table 1 Lift installation performance for all traffic demands with all lifts in service

Installation	No. of lifts	Uppeak	Down peak	Midday	Interfloor
4 car, 10 floor, Handling capacity108 P/5-minute	AWT	23	31	44	9
	90%	56	66	105	20
6 car, 14 floor, Handling capacity140 P/5-minute	AWT	30	29	35	8
	90%	60	69	82	17

As it would be expected the passenger waiting times worsen in the traffic demand sequence: uppeak, down peak and midday traffic. During interfloor activity the lifts provide an excellent service.

If passengers are prepared to wait for a lift during the peak periods, then it would be reasonable for them to wait similar times during interfloor traffic conditions. This would draw on the human psychology that a consistent response to a stimulus is preferable to a variable one. An opportunity therefore exists to take out of service, or even shut down, some of the lifts in a group during interfloor activity and still provide a suitable performance.

Table 2 shows what happens as the number of lifts available are reduced. The last column shows the performance for the worst of the peak demand periods, ie: midday. Even when the number of lifts available are halved the performance of the installation is still better than during the midday period.

Table 2 Interfloor traffic performance with a reduction in the number of lifts in service

Installation	No. of lifts	4 lifts	3 lifts	2 lifts	Midday
4 car, 10 floor Handling capacity 108 P/5-minute	AWT	9	14	39	44
	90%	20	36	92	105
		6 lifts	4 lifts	3 lifts	
6 car, 14 floor Handling capacity 140 P/5-minute	AWT	8	15	31	35
	90%	17	36	74	82

Reducing the number of cars in service would immediately save energy as the lift controllers need not be powered up or the car lighting/ventilation maintained. Additionally, the number of motor starts and the motor running time would be smaller saving more energy. Table 3 shows results from the simulations for the six car installation that indicate a 13% reduction in the number of motor starts and a 27% reduction in running time.

Table 3 Motor starts and running time during interfloor traffic for six car installation

6 Cars in service	Car 1	Car 2	Car 3	Car 4	Car 5	Car 6	Total
Total Motor Starts	97	109	112	119	125	125	687
Total running time (s)	1036	1113	1182	1221	1305	1336	7194
3 Cars in service	Car 1	Car 2	Car 3				Total
Total Motor Starts	195	201	199				596
Total running time (s)	1725	1756	1766				5247

Typically during interfloor traffic, with all cars in service, a stop is made to pick up a passenger and stop is made to drop the passenger off. Often the passenger is alone during the trip. If there are less cars in service, the car loading will increase. Because a lift system is most efficient, when the car is loaded to the counterbalancing ratio, typically 40% to 50% of rated load (see Section 5), increasing car loading leads to further energy savings. Ideally the car loading during interfloor traffic should be as close as possible to the balancing ratio.

The increased car loading, which results from reducing the number of lifts in service, thus offers additional energy savings during the morning and afternoon interfloor activity.

To summarise reducing the number of lifts in service during periods of low activity make energy savings possible with respect to: car lighting/ventilation; controller power consumption and motor power consumption, especially when car loads are close to the counterbalancing ratio. All these savings are possible without significantly affecting traffic performance.

4 DRIVE MOTOR SIZING TO THE NOTIONAL RATED CAPACITY

Table 1.1 of BS EN81-1/2, gives for lift car platform areas (from 0.9 m² to 5.0 m²), the rated loads (from 100 kg to 2,500 kg) and the rated capacity, assuming an average passenger weighs 75 kg. This is shown in Columns 1-3 of Table 4.

Table 4 Rated capacity, rated load, notional rated capacity and notional rated load as a function of platform area

1	2	3	4	5
Platform area (m ²)	Current EN81-1/2 Rated capacity (persons)	Current EN81-1/2 Rated load (kg)	Notional Rated Capacity (person)	Notional Rated load (kg)
0.90	4	300	4*	300
1.30	6	450	6*	450
1.66	8	630	8*	600
2.00	10	800	10	750
2.40	13	1000	12	900
2.95	17	1275	14*	1105
3.56	21	1600	17*	1335
3.88	24	1800	19*	1455
4.20	26	2000	21	1575
5.00	33	2500	25	1875

*rounded down

The relationship between the rated capacity and the available car area is nonlinear. For example, a car with a platform area of 1.30 m² is considered big enough for six persons, ie: an area of 0.21 m² each, whereas a car with a platform area of 5.0 m² is considered big enough for 33 persons, ie: an area of 0.15 m² for each person. (This density of persons, ie: about 6 persons per square metre, is called “crush loading”.)

The passengers are thus allocated progressively a smaller area per person as the lift cars become larger. Observations show that that passengers do not fill cars to such a high density. If it is assumed a passenger requires 0.21 m² area to stand in then Column 4 of Table 4 shows the notional rated capacity. Again assuming that the average passenger weighs 75 kg then the notional rated load need only be that shown on Column 5 of Table 4.

If passengers do not load lift cars to the densities given in Table 1.1 of EN81-1/2 then for many years the drive systems of lifts with rated loads greater than 450 kg have been oversized. For example, in the case of the 1600 kg traction lift (a popular size) this oversizing is equal to 20% and for a 2500 kg traction lift the oversizing is equal to 33%. Only under test conditions do the drive motors have to move the rated load. Because the drive motors are being oversized their iron and copper losses will be a larger proportion of the energy required leading to lower machine efficiencies. The capital costs and energy audit² of the motor, its associated drive controller, wiring, etc. will also be larger.

To ensure safe operation, the installation (suspension, ropes, rope anchorages, guidance system, car frame/platform, brake, sheave shaft loading, buffers, etc.) must continue to be sized according to the current EN81-1/2 rated loads (Table 4, Column 3). These values will cope with any possible crush loading situations. To prevent movement of the car, and

² Life cycle energy used for material extraction, processing, manufacture, transportation, human support, etc.

maintain the lift stationary, should the car become overloaded, the overload device fitted to EN81-1/2, clause 14.2.5.2 should be set to operate at 10% above the notional rated load.

A result of reducing the car loading values from the rated load to the notional rated load values is that the weight of counterweight will be smaller. A programme could be developed to remove some of the filler weights in existing lifts, which would result in immediate energy savings.

5 COUNTERBALANCING RATIO AND VARIABLE SPEED DRIVES

The drive motor of a traction lift is required to move the load of the passengers in the car. In order to reduce the size of the drive motor, the weight of the car³ plus a proportion of the maximum weight of the passengers (the rated load) is balanced by a counterweight. The commonly used value for the counterbalancing ratio is 50%. For a lift with 50% counterbalancing, when it is half full with passengers, the motor only needs to overcome various losses in order to move the lift. However, is the value of 50% correct? It has been observed that some lift designers use values as low as 40% leading to the conclusion that it has already been recognised by some designers that lifts do not fill to the rated capacity.

The output (R) of a lift motor with an efficiency (η) is related to the out-of-balance load (B) and rated speed (v) by:

$$R = 0.981 \times \frac{B \times v}{\eta} \quad \dots (1)$$

Suppose the counterbalancing ratio were set at 33 $\frac{1}{3}$ %. What effect does this have? In the range of passenger load from zero to two thirds rated load, the drive motor is working within its capacity. If the car fills to the rated load, then the drive motor must supply twice its rating. This will cause the motor and the drive to be overloaded. There is a solution however.

According to Equation (1) if the out-of-balance load has doubled then the motor speed must be halved, in order for the drive motor to work within its rating. As a drive motor normally operates in the range of zero speed to rated speed, drive controls should be able to set a target speed lower than rated speed in proportion to the passenger load in the car.

The consequence of running at a slower speed is that the lift will take longer to move between floors and this would have a some effect on handling capacity in peak demand periods. However, the effect would lessen as passengers leave the car thus reducing the loading.

As an example consider: four lifts, rated load 1,800 kg, running at 2.0 m/s with 42% counterbalancing. The maximum out-of-balance load will be for a fully loaded car travelling up, ie: 1044 kg (0.58 \times 1800). The motor size assuming 90% efficiency could be:

$$R = 0.981 \times 0.58 \times 1800 \times 2/90 = 22.8 \text{ kW}$$

³ Typically the weight of the car is more than twice that of the rated load carried.

Now suppose that the counterbalancing were to be reduced from 42% to 33⅓% and the maximum out-of-balance load assumed to be 600 kg the motor size would become:

$$R = 0.981 \times 0.333 \times 1800 \times 2/90 = 13.1 \text{ kW}$$

If the load in the car less than 1200 kg then the lift can run at the rated speed. If the load in the car is 1800 kg the speed will need to be reduced to 1.0 m/s. For loads between 1200 kg and 1800 kg the speed would be in the range 1.0 m/s to 2.0 m/s.

A further effect can be considered. The notional (realistic) maximum passenger loading of a lift with a rated load of 1800 kg and a platform area of 3.88 m² is 1455 kg (see Table 4). With a 33⅓% counterbalancing the required motor rating can be reduced to:

$$R = 0.981 \times 0.333 \times 1455 \times 2/90 = 10.6 \text{ kW}$$

The example illustrates the effect of considering a counterbalancing of 33⅓% and the notional rated capacity. The result is a drive motor rating of about half the installed size.

For safe operation the lift must continue to be sized according to the current EN81-1/2 rated loads (Table 4, Column 3) to cope with any possible crush loading situations. The overload device fitted to EN81-1/2, clause 14.2.5.2 should be set to operate at 10% above the notional rated load. Additionally, the drive system heat sinks and the drive machine windings should be temperature monitored according to Clause 13.3.6/13.3.5 of BS EN81-1/2 to ensure the drive system operates within its temperature rating.

The consequences of a lower counterbalancing ratio are:

- (a) A smaller motor and controlling drive unit are required leading to a lower energy usage.
- (b) The drive control system would need to detect the car load and set the target speed to meet the requirements of Equation (1).
- (c) Adopting the nominal capacity values indicated in Table 4 would permit an even smaller counterweight to be used and further energy savings can be made.
- (d) Traffic calculations would need to take into account the variable speed and increased flight times that occur.

6 CONCLUSIONS

Energy can be saved on lift installations by a number of actions, some of which are inexpensive and simple to implement. These include:

- Turn off the car lights and auxiliaries, and the power side of the lift controller, after a lift has not been used for 5-minutes.
- Shut down lifts during periods of low traffic demand.
- Re-evaluate the realistic number of passengers a lift can accommodate.
- Reduce the counterbalancing weight to match the realistic number of passengers a lift can accommodate.
- Reduce the drive motor size to match the realistic number of passengers a lift can accommodate.
- Re-evaluate the counterbalancing ratio from 50% to 33⅓%.
- Reduce drive motor size to match the new counterbalancing ratio.
- Provide a drive controller capable of variable-speed, variable-voltage, variable-frequency (V^3SVF) control of the drive motor.

The suggestions above are win/win outcomes for owner, consultant, supplier and installer, as the payback periods should be quite short.

REFERENCES

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Biographical details

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