Symposium on Lift and Escalator Technologies

Energy Models for Lifts[1]

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ABSTRACT

"*Energy modelling is a complex subject*" – Peters *et al*, 2004 [3]

The intention of this paper is (1) to explain some work which is being carried out at the International Standards Organisation (ISO) level (2) to suggest a simple energy reference model to support this work; and (3) to develop a simple energy model that could be employed in a public domain traffic simulation program to predict energy consumption.

1 ISO DRAFT STANDARD DIS/25745-1

A Working Group of an International Standards Organisation's Technical Committee (TC178/WG10) has developed a draft standard DIS/25745-1 "*Energy performance of lifts, escalators and moving walks – Part 1 Energy and verification*". This standard sets out the procedures to be used when making energy measurements and verifying that energy usage during the life cycle of a lift installation. It does not grade, or provide energy certification for lifts, escalator and moving walks as happens now for boilers, refrigerators, washing machines, etc.

The Working Group has proposed a simple pragmatic procedure that should be easy to carry out, uses readily available measuring equipment, is repeatable, and allows periodic verification checks to be carried out.

2 ENERGY MEASUREMENT FOR A ISO REFERENCE CYCLE

The proposal is to measure the running energy consumed by a lift during a ISO Reference Cycle. The ISO Reference Cycle comprises running an empty lift car from one extreme landing (highest/lowest) to the other extreme landing (lowest/highest) and back again. The lift carries out one cycle of its normal door operations at each terminal landing. These include opening, closing and dwell times. The energy consumed for at least ten cycles should be measured and an average energy consumption value (in Wh) for a single ISO Reference Cycle determined.

Care needs to be taken to ensure all the energy used to operate the lift is included. For example sometimes the main power and the ancillary power (lights, fans, alarms, trickle chargers, displays, etc.) are often supplied by separate feeders. Non lift function energy consumers such as car and machine room heating, cooling and lighting are not to be included.

After the terminal landings cycling test the lift should be maintained stationary, for five minutes, at one terminal landing. A power measurement (in W) can then be made. This gives the standby power consumed. "Green" lift equipment manufacturers will thus be sure to reduce the idle power consumption by turning off all energy hungry lighting and controllers within this five minute period of grace.

The procedure just described requires a fairly sophisticated energy/power measuring instrument together with a skilled operator. So the second part of the standard indicates how to verify continuing energy consumption. This can be achieved by measuring the line currents at the same time as the energy measurements are made. Later an inexpensive, simple current meter (amp

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probe), applied by the less skilled service mechanic, can be used to detect any changes in the energy consumption. For example, the car might become heavier if it was re-fitted with mirrors (more energy consumed); or the less energy demanding if the incandescent car lighting were to be replaced by low energy units (less energy consumed). Or the door timings might have changed.

The currents that are measured for the verification check do not necessarily need to be exactly in proportion to the energy graph as the power factor (cosφ) values at the different car loadings will vary. However, if as time passes these current values do not change, then it can be assumed that the energy consumption remains the same as it was when first measured and the verification current readings taken.

This energy/power/current measurement procedure can be part of the final commissioning tests for a new lift and could be carried out for an existing lift on request.

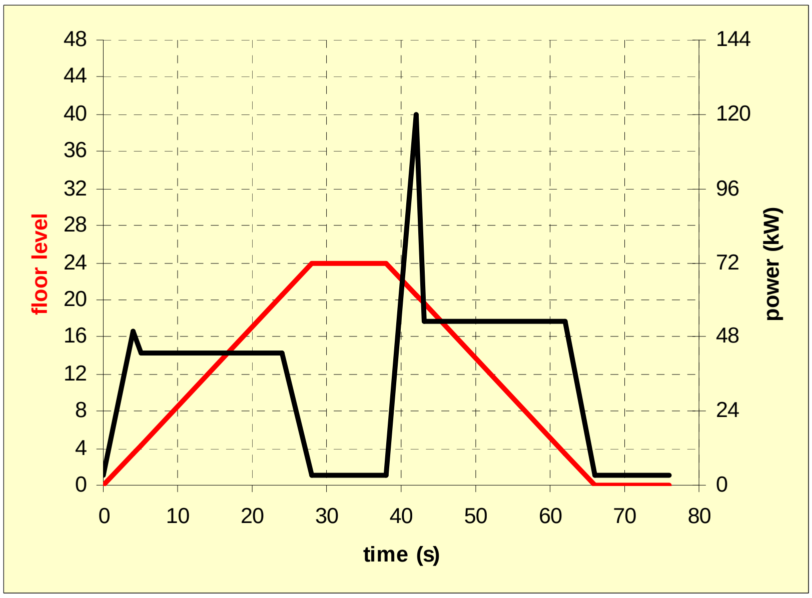

Figure 1 Idealised ISO Reference Cycle

Figure 1 illustrates an idealised ISO Reference Cycle where the empty lift moves from the lowest terminal floor (red line) to the highest terminal floor, carries out its door operations, returns to the lowest terminal floor and carries out its door operations. The power consumed (black line) shows a lower, power consumption as the empty car moves up, under the influence of the (heavier) counterweight, than when the empty car moves down, pulling up the counterweight.

3 ENERGY REFERENCE VALUES FOR A LIFT

The lift now has two measured values: one for the running energy consumed (Wh) during a ISO Reference Cycle and another for the power consumed (W) when in standby mode. These figures apply only to the lift that has been measured and no other. No two lifts are the same even if they share the same rated load and rated speed and are in the same building. Obvious differences include: the travel distance between terminal landings, different door operating times, no of entrances, the counterbalancing ratio, the weight of the car, car balance, the type of guide shoes, roping factor, number of car entrances, drive system, effect of the maintenance regime, etc, etc.

If a purchaser of a lift wishes to be seen to be "green", or is required to be by the terms of any building energy certification process, then the two reference figures should be obtained before an order is placed.

So where do these figures come from?

It is expected that suppliers will know their product sufficiently well (after all they have sized the drive machine and the indicated the supply cable specification, etc.). It is also to be hoped that they will have energy models available for their products and thus be able to easily supply these two figures. Of course the purchaser will confirm them at the time of final test. Energy consumption could thus become a selection criterion between manufacturers.

4 THE ISO REFERENCE CYCLE

How can a simple ISO Reference Cycle model be developed?

Figure 1 shows an idealised ISO Reference Cycle, which comprises four main parts:

(1) power consumption for an empty car travelling up (28 s)
(2) door operation at the highest landing (10 s)
(3) power consumption for an empty car travelling down (28 s)
(4) door operations at the lowest landing (10 s)

The parts (1) and (3) are further subdivided. There is a peak power on start up, which reduces to the running power when rated speed is reached. At the end of the running time the power falls to the idle power (1.0 kW). Remember idle power is not standby power. It is the power consumed between the lift running and it entering the standby mode of operation.

The energy consumed during the ISO Reference Cycle is the area under the graph in Figure 1, in watt-hours (Wh). This can be simply calculated as a set of triangles and rectangles.

5 OBTAINING DATA FOR THE MODEL

The data required are:

Peak power up empty
Running power up empty (at rated speed)
Peak power down empty
Running power down empty (at rated speed)

Time to reach peak power up
Time to reach rated speed up
Time to reach peak power down
Time to reach rated speed down

Door timings

The idealised graph in Figure 1 assumes:

> the time to reach the peak power from starting up (or down) is equal to the theoretical time to reach the rated speed (*tvm*)

and

> the time from reaching peak power to falling to the running power value (at rated speed) is equal to 1.25 *tvm* (125%).

These are reasonable approximations. The time (*tvm*) to reach rated speed (*vm*) is given by:

$$tvm = \frac{vm}{a} + \frac{a}{j} \quad \text{(source CIBSE Guide D: 2010, A2-2 [2])}$$

where: a is the value for acceleration (m/s^2); j is the value for jerk (m/s^3)

6 EXAMPLES OF THE USE OF A SIMPLE ISO REFERENCE CYCLE MODEL

Al-Sharif, Peters and Smith [3] in 2004 obtained data for a lift with a rated load of 1800 kg and a rated speed of 2.0 m/s with 42% counterbalancing. The lift had a regenerative drive. Power data for up and down movements with 0%, 25%, 50% 75% and 100% car loads were obtained. Figure 2 shows a graph of this installation using the data for an empty car (0%) given in Table 1 for a car starting at the highest terminal floor.

Table 1 Spot data for a regenerative drive system (1800 kg)

Car load (kg)	Car load (%)	Power running down (kW)	Power starting down (kW)	Power running up (kW)	Power starting up (kW)
0	0	23	30	– 9.0	3.0

The numbers are rounded for simplicity. The idle power is 2.0 kW.

So what does a simple energy model using this data look like? A plot of the power used by an empty car for a downwards trip would look something like the Figure 3, which is a close facsimile of Figure 2. The calculation of energy used (the area under the curve) gives:

Running energy down	110.7 Wh
Running energy up	-34.9 Wh
Total running energy	75.8 Wh
Door operations	8.9 Wh
Total energy	84.7 Wh

As the ISO Reference Cycle occupied 56 seconds, if cycling had continued for one hour (about 64 Reference Cycles, 128 stops) the energy consumed would be 5.4 kWh (cost about £0.54 at 10p per kWh).

Figure 4 is example based on measurements for another lift. It shows an ISO Reference Cycle for an empty car trip down and then up between terminal floors. This lift has a rated load of 1500 kg, a rated speed of 4.0 m/s, is in a 24 floor building with a 62 HP (46.3 kW) hoist motor, 50% counterbalanced. The black line shows the power consumed. The plot is idealised, an actual plot will have irregularities similar to those shown in Figure 2. The values are from the empty (0%) car load row in Table 2.

Table 2: Data from actual (1500 kg) installation used to obtain Figure 4

Car load (kg)	Car load (%)	Power (kW)			
		running down	starting down	running up	starting up
0	0	53	120	43	50
750	50	13*	100	13*	100
1500	100	43	70	53	130

* 3.0 kW is controller plus ancillaries =10 kW for inefficiency.

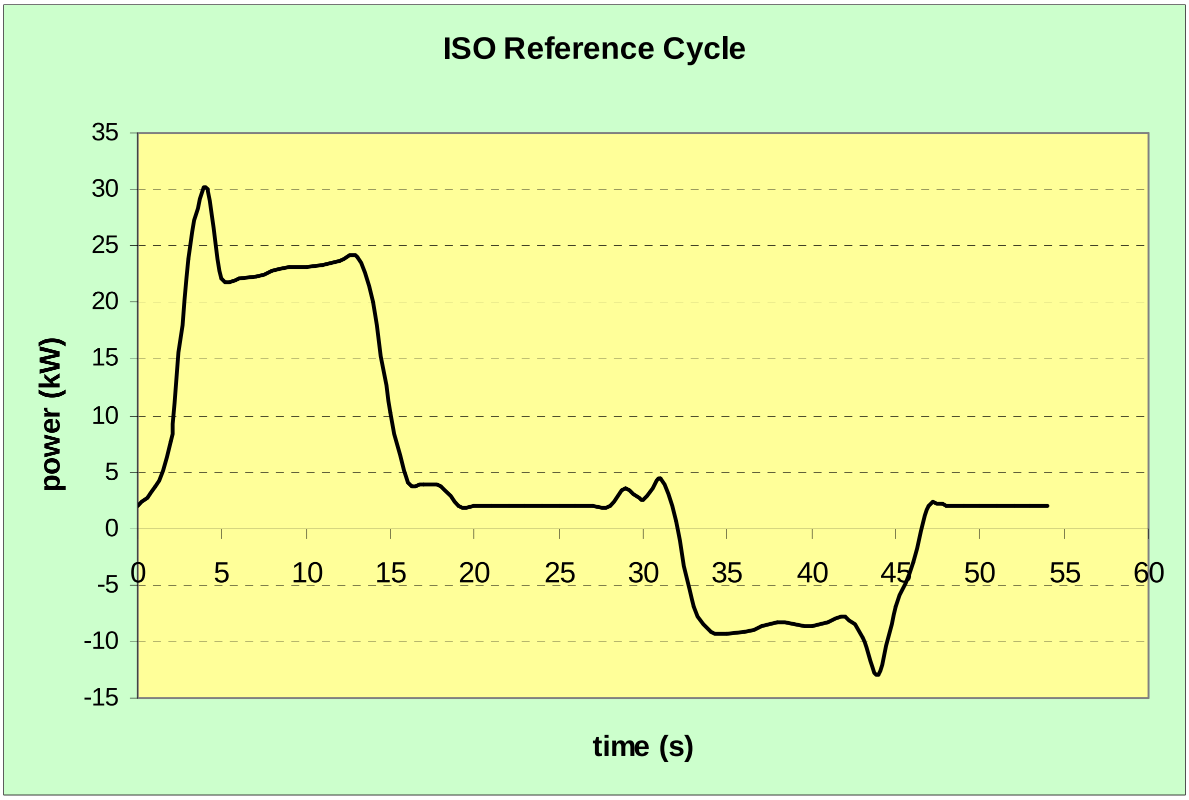

Figure 2: An ISO Reference Cycle for an empty car (1800 kg lift)

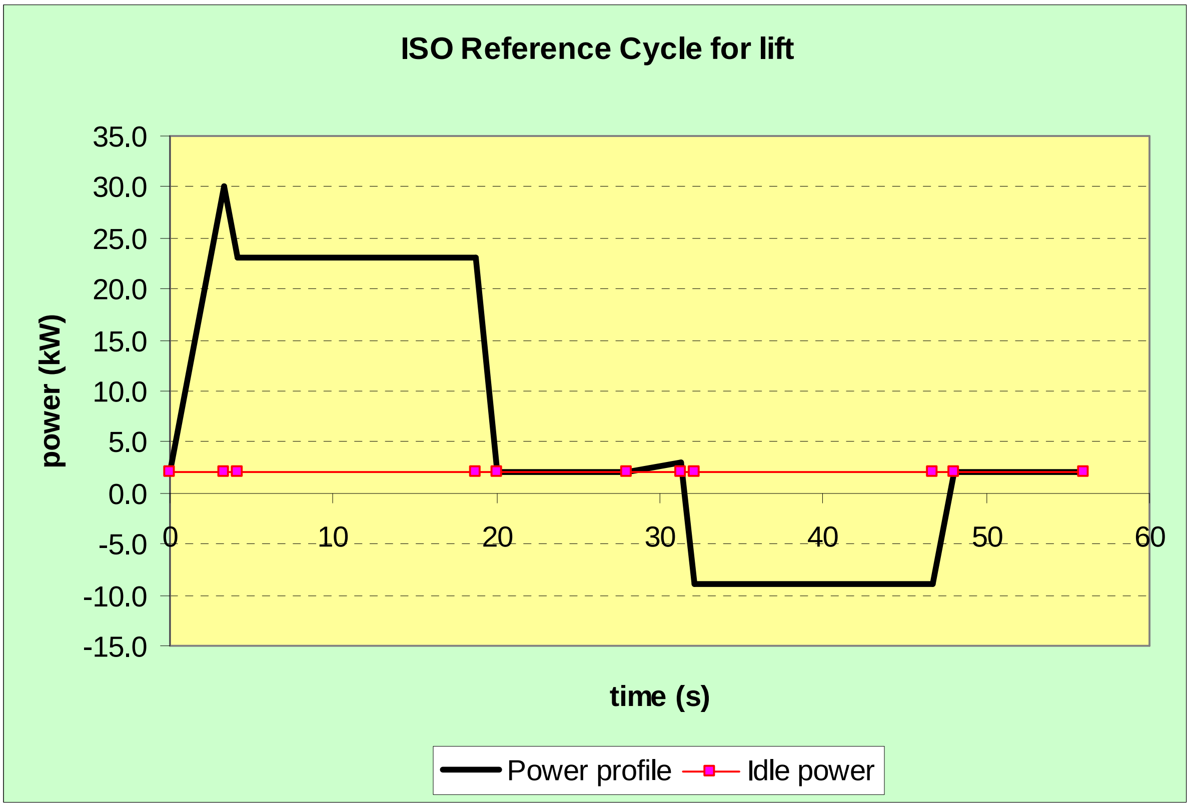

Figure 3 Model plot for installation of Figure 2 (1800 kg lift)

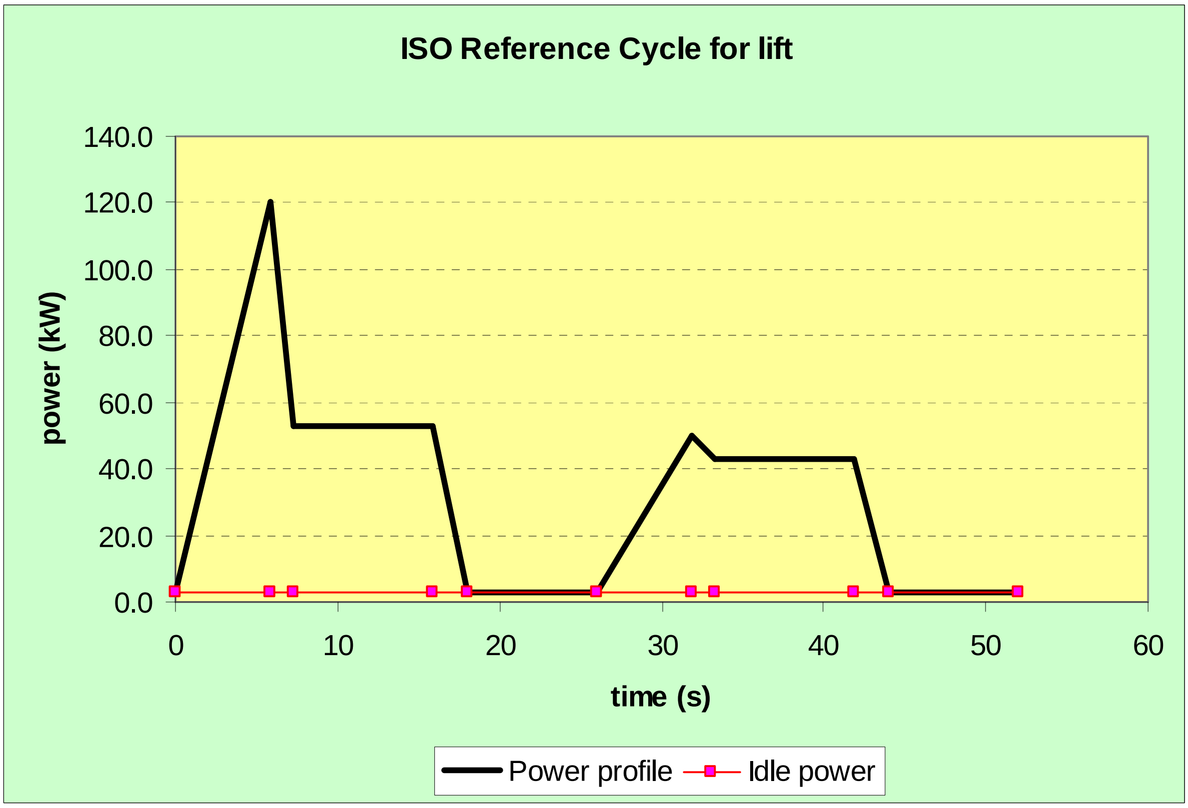

Figure 4 Reference cycle for a 24 floor office building (1500 kg lift)

Table 2 also shows the power required for starting and running for the car loads of 50% (balance) and 100% car loading in both directions of travel. These entries were obtained from the record made[2] when the lift was tested in 1993.

It is interesting to note that at balanced load (50%) the power taken is 13 kW. This is made up of 3 kW idle power supplying the controllers and ancillaries and 10 kW to overcome inefficiencies.

7 TRAFFIC PATTERNS

No one can predict the usage pattern of a lift (Barney: 2003 [1]). It is a bit like predicting how the stock market will perform. Many assumptions are made by experienced traffic designers when sizing a lift installation. This is why some naïve developers get it wrong as they lack that experience.

Traffic simulators are used to study the behaviour of a particular design. Thus it would be useful to be able to study the energy behaviour at the same time.

This is possible as a lift traffic simulator "knows" the passenger load in the car, the direction of travel, the number of passengers entering/leaving, the travel distance, door timings, etc. If the power used for each individual car load and each individual direction and distance of travel were known (they could be in a matrix) then the simulator could estimate energy consumption.

To insert an energy model into a traffic simulation program requires more data than shown in Table 2. However, Table 2 provides enough entries to establish Table 3, by assuming a linear

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[2] The document used was BS5655-10: 1986 "Certificate of test and examination for lifts" and the data was recorded in Section A5(c) "Measurement of the electrical system" for empty, balanced and fully loaded cars. The latest test documents (PAS32/BS8486) do not record such data).

relationship between the grey cell entries. In practice the relationship will be nonlinear. Thus a simple table can be developed for use in a traffic simulator.

Table 3: Extended entries (1500 kg lift)

Car load (kg)	Car load (%)	Power (kW)			
		running down	starting down	running up	starting up
0	0	53	120	43	50
75	5	49	118	40	55
150	10	45	116	37	60
225	15	41	114	34	65
300	20	37	112	31	70
375	25	33	110	28	75
450	30	29	108	25	80
525	35	25	106	22	85
600	40	21	104	19	90
675	45	17	102	16	95
750	50	13*	100	13*	100
825	55	16	97	17	103
900	60	19	94	21	106
975	65	22	91	25	109
1050	70	25	88	29	112
1125	75	28	85	33	115
1200	80	31	82	37	118
1275	85	34	79	41	121
1350	90	37	76	45	124
1425	95	40	73	49	127
1500	100	43	70	53	130

8 EXAMPLES OF AN ENERGY MODEL IN A SIMULATION PROGRAM

8.1 Uppeak traffic

Consider Figure 5. This shows the spatial movements (red line) of the example 1,500 kg lift during the morning uppeak traffic demand. Table 4 gives the data used.

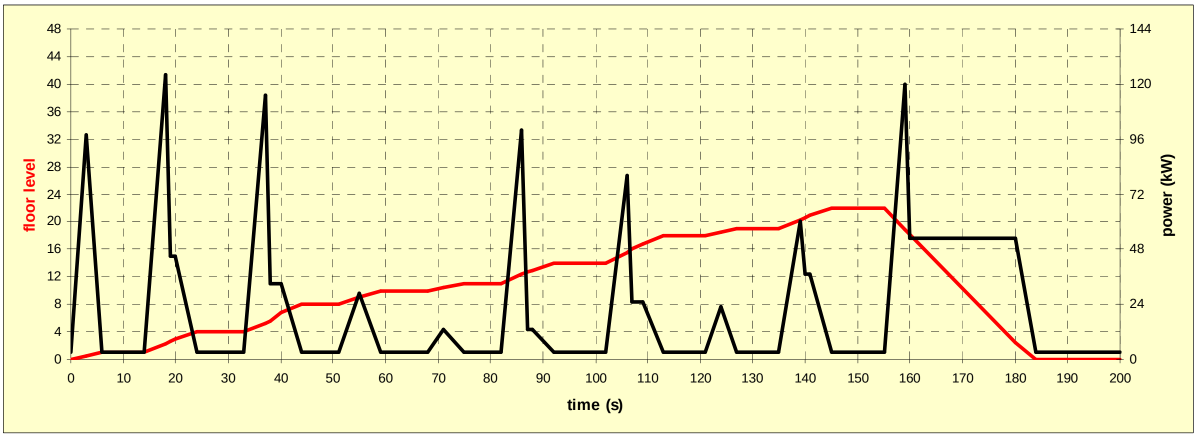

Figure 5 Power profile for a typical uppeak traffic pattern (1500 kg lift)

The lift leaves Floor 0 with 20 passengers and calls at nine floors with various numbers of passengers alighting. Thus the load reduces until the last passengers exit at Floor 22. The lift then returns empty to Floor 0. Note the balance load is achieved as the lift leaves Floor 11.

Where the lift only moves one floor, eg: 0>1, 10>11, 18>19 the graph shows a low peak power as rated speed is not reached (shown * in Table 4). Where the lift moves two floor, eg: 8>10 rated speed is just reached before the slow down sequence is initiated. In all other cases the lift reaches rated speed as indicated by the step in the profile, although it may only be for a short time, eg: 1>4, 19>22.

The energy profile has been idealised for the purpose of illustration. This would not be necessary in a simulation program as the actual profiles can be calculated. Once again the energy consumed is the area under the profile. This can be easily calculated by a simulation program.

Table 4: Data used to construct Figure 5 (1500 kg lift) (figures rounded)

Floor	**Number of passengers**			**Car load (%)**	**Peak power starting (kW)**	**Running power (kW)**	**Total door operating time (s)**
	In car on arrival at floor	**Leaving car at floor**	**In car on departure from floor**				
0	0	0	20	100	130/98*	n/a	0
1	20	2	18	90	124	45	8
4	18	3	15	75	115	33	9
8	15	1	14	70	29	n/a	7
10	14	3	11	55	17/13*	n/a	9
11	11	1	10	50	100	13	7
14	10	4	6	30	80	25	10
18	6	2	4	20	31/23*	n/a	8
19	4	2	2	10	60	37	8
22	2	2	0	0	120	53	8
Other data are: Time to reach rated speed: 4.0 s. Passenger transfer time 1.0 s per passenger. Flight times: one floor – 6.0 s, two floors – 8.0 s, three floors – 9.0 s, four floors – 10.0 s. Door open and door closing times: 3.0 s each. * Single floor jumps – peak not reached.							

8.2 Down peak traffic

Figure 6 shows a down peak traffic situation for the example 1,800 kg lift. It loads six passengers at Floor 20, which takes 10 seconds including door times. The lift then successively calls at Floors 19, 18 and 17 loading six passengers each. Because the flight time between two adjacent floors is only six seconds the peak starting currents are not reached and are estimated at 2/3rds of the measured peak. Once the lift leaves Floor 17 it regenerates power back into the mains supply. It should be noticed that of the 80 seconds from loading at Floor 20 until the lift arrives at Floor 0, the lift is only moving for 40 seconds.

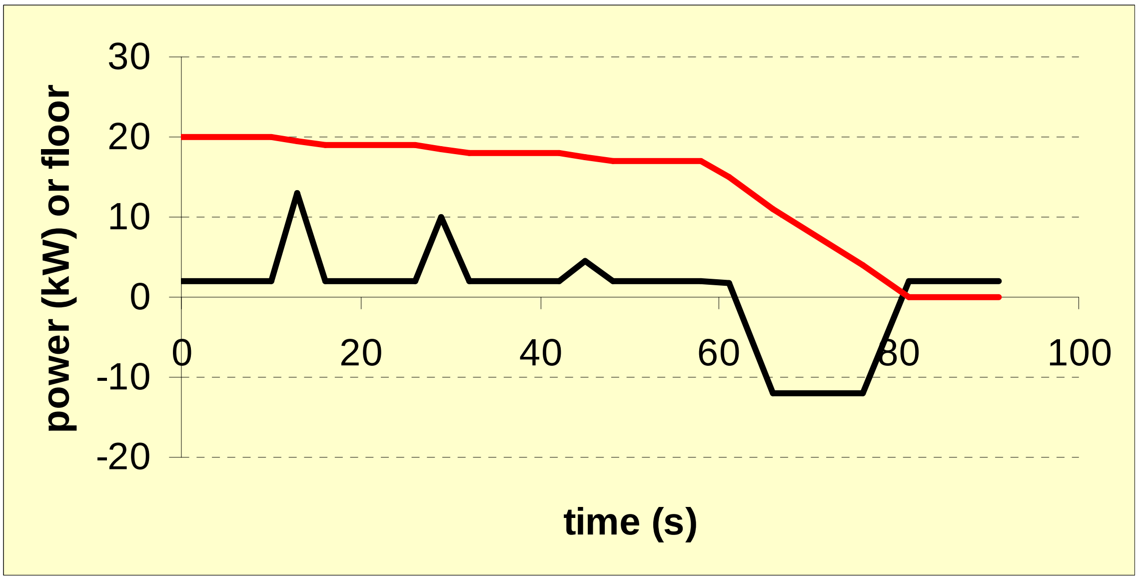

Figure 6 Power profile for a typical down peak traffic profile (1800 kg lift)

9 DISCUSSION AND CONCLUSIONS

The method for taking energy measurements of an actual system using the ISO Reference Cycle will be as accurate as the instruments used and the skill of the user. The same conditions apply to the electrical current measurements made for verification. The two measurements obtained should give a good view of how well a lift is performing at the time of measurement and over time.

Prediction of the two ISO numbers is not difficult. The simple energy model proposed, based on the ISO Reference Cycle, relies on a number of simplifications, as discussed in Section 5. Errors in the values used will affect the shape of the power/energy profile as shown in Figures 2 and 3. However the energy used in the peaks is small compared to that used when the lift is running. As the running power is likely to be known with good accuracy, little error should occur. In any case lift suppliers usually know their product very well and will have accurate values for all these parameters.

Energy usage prediction is much more difficult. The simple model proposed can be employed to calculate energy usage. More data is required, which used to be collected when a lift was commissioned (tested/adjusted). This data, as shown in Table 2, enables an interpolation on a linear basis. This is not strictly correct as electric motors are magnetic devices and exhibit significant nonlinearities. Using data such as that shown in Section 8 allows a reasonable attempt to be made to predict the energy used for SPECIFIC traffic patterns. A striking feature is how little energy is used.

It is important to note that a real energy profile varies with the direction of travel and car position in the well, and is not symmetrical, ie: exhibits nonlinearity.

Figure 5 shows an energy profile for uppeak traffic and Figure 6 shows the energy profile for a down peak traffic. These emulations are not precise, but, if the proposed model is embedded in a simulation program, then a more precise calculation can be made, which will be as accurate as the data provided.

The energy measurement of building services is being required more and more by various regulations, for example, in order to comply with the energy certification of buildings. Modern lifts (and some older ones too) are already very efficient, especially those based on counterbalanced systems. However, it is wise to prove this to energy inspectors and standard methods of energy measurements, conformance checking and modelling are necessary to do this.

It can be expected that third party[3] and manufacturer modelling and simulation programs will include energy modelling as the need for it arises. It will then be possible to more accurately predict energy usage. This can be particularly useful when considering energy reduction measures.

REFERENCES

[1] Barney, Gina, "Elevator Traffic Handbook – Theory and Practice", Spon Press, 2003

[2] Peters, R., CIBSE Guide D: 2010[4]: "Transportation systems in buildings", Appendix A2, September 2010.

[3] al-Sharif, L., Peters R. and Smith, R, "Elevator Energy Simulation Model", IAEE, Elevator Technology 14, April 2004.

WARNING

The data used to plot the graphs are based on real systems, but they have been idealised and the numbers rounded to illustrate the discussion.

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[3] Visit www.peters-research.com

[4] Visit www.cibse.org