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Simplified Energy Calculations for Lifts Based on ISO/DIS 25745-2

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Abstract. It is often necessary to select the best performing lift installation in terms of energy efficiency, for example, to gain the first credit in the BREEAM classification system[1]. Previous energy consumption calculation methods have been inaccurate such as that suggested in CIBSE Guide D: 2010 [2]. A more accurate method has been developed by an International Standards Organisation Working Group (ISO/TC178/WG10) and this was published in ISO/DIS 25745-2 [3] on 6 June 2013. A simplified form of the calculation method is given here, together with a more exact method.

1 GIVEN DATA

The method relies on knowledge of three data sets: known data, measured data and estimated data.

Known data for the target installation is the design data. These data are: rated speed; rated load; acceleration value; jerk value, terminal floor to terminal floor distance; the number of stops; the time for the opening, opened and closing times of the lift doors at the landings; counter balancing ratio.

Measured data is obtained using the method specified in EN ISO 25745-1: 2012 [1] either from an actual target installation or a test tower facility set to emulate the target installation. These data are: running energy consumption in the reference cycle defined by the standard; standing idle energy consumption; standing standby energy[2]. In the absence of measured data, values obtained by simulation may be used.

Estimated data is an indication of the activity of the installation ranging from very low to very high activity. This data is represented by the number of trips per day.

2 ESTIMATED DAILY ENERGY CONSUMPTION

The estimated daily energy consumption (E_d) of a lift is the sum of the running consumption (E_{rd}) and the standing (idle/standby) consumption (E_{sd}):

$$E_d = E_{rd} + E_{sd} \qquad \dots (1)$$

3 ESTIMATED DAILY RUNNING ENERGY CONSUMPTION

The daily running consumption (E_{rd}) is dependant on the energy used for an average trip that the target lift makes multiplied by the number of trips in a day (n_d).

The running energy consumption (E_{rc}) used to perform the ISO reference cycle[3] is given by the measurement made according to EN ISO 25745-1: 2012 [1].

[1] Other building classifications exist such as LEEDS, Green Star, etc.
[2] These terms are defined in BS EN ISO 25745-1: 2012
[3] The ISO reference cycle is an outwards travel of an empty car from one terminal landing to the other terminal landing and return.

This running energy measurement is for an empty car travelling the distance between the terminal landings (s_{rc}). The distance travelled for an average trip (s_{av}) is less then the distance between the terminal landings and can be expressed as a percentage of the distance (s_{rc}), ie: as $\%S = s_{av}/s_{rc}$.

The running energy measurement is made with an empty car. In operation the lift will carry passenger loads from zero to full rated load. In general the average loading is low. For loaded cars the running energy needs to be multiplied by a load factor (k_L). This factor is used to correct the value of energy consumption of lifts travelling empty in relation to an average load spectrum and is obtained multiplying the % of the trip ratio by the percentage of the reference trip energy consumed.

Thus the daily running consumption (E_{rd}) in Wh is given by Equation 2:

$$E_{rd} = \frac{n_d \times \%S \times k_L \times E_{rc}}{2} \quad \ldots (2)$$

where:

n_d is the number of trips per day[4]
$\%S$ is the percentage average travel distance per trip for a target installation
k_L is the load factor per trip
E_{rc} is the measured or estimated running energy consumption of the ISO reference cycle (two trips) in Wh.

The number of trips per day (n_d) for a target installation is either known, or can be estimated, or taken from ISO-Table 1 [3]. The number of trips defines the usage category for any calculations. ISO Part 2 includes an additional usage category (Category 6)

The tables available in ISO/DIS 25745-2 correspond to average buildings with an homogeneous distribution of the population per floor and no express zones, in which the lift service out of the working hours and during the weekends follow general patterns for offices and for residential buildings. When the target building has an inhomogeneous distribution of the population or shows an unconventional operation it may be necessary to perform on site traffic measurements or simulations. The load factors of the standard also include an estimation of the traffic distribution.

ISO-Table 1: Categorized number of starts per day[5]

Usage category	**1**	**2**	**3**	**4**	**5**
Usage intensity	**very low**	**low**	**medium**	**high**	**very high**
Number of trips per day (n_d)	50	125	300	750	1500
Typical range	<75	75-200	200-500	500-1000	1000-2000

The percentage average travel distance ($\%S$) can be taken from ISO-Table 2 [3] based on the usage category selected and the number of possible stops in the served building.

[4] A trip is a movement from one floor to another.
[5] The ISO standard has a usage category 6, which is greater than 2000 trips per day and which is not considered here as it is only likely to arise in extreme circumstances.

ISO-Table 2: Percentage of average travel distance (%S)

Usage category	**1 – 4**	**5**
Number of stops	**Percentage average travel distance**	
2	100%	
3	67% #	
>3	44%	33%

The value suggested may need to be reviewed, if the traffic movement between the two terminal floors is dominant. In this case the average travel distance may tend towards 100%.

Note the number of stops for the target installation is a known data.

The value for the load factor (k_L) can be calculated using ISO-Equations 3a – 3e below, where the value for percentage average car load (%Q) is taken from ISO-Table 3 [3] according to the usage category and the rated load.

Note the rated load (Q) of the target installation is a known data.

ISO-Table 3 Average car load

Usage category	**1 - 3**	**4**	**5**
Rated load (kg)	**Percentage of rated load (%*Q*)**		
≤ 800	7.5	9.0	16.0
801 – ≤1275	4.5	6.0	11.0
1276 – ≤ 2000	3.0	3.5	7.0
>2000	2.0	2.2	4.5

For traction lifts counter balanced to 50%

$$k_L = 1 - (\%Q \times 0.0164) \quad \text{... (3a)}$$

Range 0.97 – 0.74.

For traction lifts counter balanced to 40%

$$k_L = 1 - (\%Q \times 0.0192) \quad \text{... (3b)}$$

Range 0.96 – 0.69.

For hydraulic lifts with no counter balancing

$$k_L = 1 + (\%Q \times 0.0071) \quad \text{... (3c)}$$

Range 1.02 – 1.11.

For hydraulic lifts with 35% counter balancing of the car weight

$$k_L = 1 + (\%Q \times 0.0100) \quad \text{... (3d)}$$

Range 1.02 – 1.16.

For hydraulic lifts with 70% counter balancing of the car weight

$k_L = 1 + (\%Q \times 0.0187)$ ... (3e)

Range 1.04 – 1.30.

The first three equations represent common traction and hydraulic lifts. The parameters given in these equations were developed from a computer model of a lift system applying a simple traffic pattern for a set of lift loads. More sophisticated traffic patterns can result in different load factors. The range shown is for the lowest and highest %Q values in ISO-Table 3 [3]. It should be noted that a load in a traction lift reduces energy usage and in a hydraulic lift increases energy usage.

4 ESTIMATED DAILY STANDING ENERGY CONSUMPTION

The daily standing (idle/standby) energy consumption comprises two main components:

$$E_{sd} = (24 - \frac{n_d}{3600} t_{av})\left(P_{id} R_{id} + P_{st} R_{st}\right) \quad \text{... (4)}$$

where:

- P_{id} is the power used when the lift is in idle mode (W) (measured after door operations have ceased when stopped at a landing.)
- P_{st} is the power used when the lift is in standby mode (W) (measured after 5 minutes of inactivity.)
- R_{id} is the ratio of idle time when consuming P_{id} (value<1)
- R_{st} is the ratio of standby time when consuming P_{st} (value<1)
- t_{av} is the time to travel the average travel distance for the target installation, including door times (s)

Note the first term in Equation 4 is the time the lift is not running, ie: standing.

The idle power and the standby power are measured values obtained by the method given in EN ISO 25745-1: 2012 [1]. The idle power is measured with an empty car and when door operations have ceased. Standby power is measured after 5 minutes of inactivity.

The ISO method considers systems that may stay in a second standby mode up to 30 minutes. This not considered here.

The values for R_{id} and R_{st} can be taken from ISO-Table 4 [3].

The time (t_{av}) to travel the average distance (s_{av}) is given by Equation 5:

$$t_{av=} \frac{s_{av}}{v} + \frac{v}{a} + \frac{a}{j} + t_d \quad \text{... (5)}$$

where:

- v is the rated speed (m/s)
- j is the rated jerk (m/s^2)
- t_d is the time for the opening, opened and closing times of the lift doors at the landings (s)

ISO-Table 4: Time ratios in idle and standby modes

Usage category		1	2	3	4	5
Time ratios (<1)	R_{id}	0.13	0.23	0.36	0.45	0.42
	R_{st}	0.87	0.77	0.64	0.55	0.58

5 EXAMPLES

5.1 Example 1 – traction lift

(from SAFE S24[6] with rounded values for easier arithmetic)

Lift parameters

Traction lift in an office building
Rated load 1,600 kg
Rated speed 2.50 m/s
Travel 75 m
Number of stops 20
Counterbalancing 50%
Acceleration 1.0 m/s^2
Jerk 1.25 m/s^3
Door times 8.0 s

Data determined by measurement or simulation

Idle power 500 W
Standby power after 5-minutes 120 W
ISO reference cycle energy 170 Wh

Estimated Data

Daily trips 1500 (category 5)

Data from tables

Average travel distance 33% [from Table 2]
Average car load 7.0% [from Table 3]
Load factor (k_L) 0.89 [from $k_L = 1 - (\%Q \times 0.0164)$]
Idle/Standby time ratio 42/58 [from Table 4]

Calculation of daily running energy consumption

$$E_{rd} = \frac{n_d \times \%S \times k_L \times E_{rc}}{2} = \frac{1500 \times 0.33 \times 0.89 \times 170}{2}$$

= 37,447 Wh

Calculation of daily standing energy consumption

$s_{av} = 0.33 \times 75 = 25$ m
$t_{av} = 25/2.5 + 2.5/1 + 1/1.25 + 8 = 21.3$ s

$$E_{sd} = (24 - \frac{n_d}{3600} t_{av})\left(P_{id}R_{id} + P_{st}R_{st}\right) = (24 - \frac{1500}{3600} 21.3)\left(500 \times 0.42 + 120 \times 0.58\right)$$

= 4,229 Wh

Calculation of daily energy consumption

$E_d = 37{,}447 + 4{,}229 = 41{,}676$ Wh

This is 42 kWh per day[7].

[6] SAFE Swiss Federal Office of Energy, 2005. http://www.electricityresearch.ch.
[7] About 0.4p (0.4c) per trip!

5.2 Example 2 – hydraulic lift

(from SAFE S3 with rounded values for easier arithmetic)

Lift parameters

Hydraulic lift in a residential building
Rated load 500 kg
Rated speed 0.6 m/s
Travel 13 m
Number of stops 5
Counterbalancing 0%
Acceleration 0.3 m/s^2
Jerk 0.5 m/s^3
Door times 8.0 s

Data determined by measurement or simulation

Idle power 50 W
Standby power after 5-minutes 31 W
ISO reference cycle energy 91 Wh

Estimated Data

Daily trips 30 (category 1)

Data from tables

Average travel distance 44% [from Table 2]
Average car load 7.5% [from Table 3]
Load factor (k_L) 1.05 [from $k_L = 1 + (\%Q \times 0.0071)$]
Idle/Standby time ratio 13/87 [from Table 4]

Calculation daily running energy consumption

$$E_{rd} = \frac{n_d \times \%S \times k_L \times E_{rc}}{2} = \frac{30 \times 0.44 \times 1.05 \times 91}{2}$$

= 631 Wh

Calculation daily standing energy consumption

$s_{av} = 0.44 \times 13 = 5.7$ m
$t_{av} = 5.7/0.6 + 0.6/0.3 + 0.3/0.5 + 8 = 20.1$ s

$$E_{sd} = (24 - \frac{n_d}{3600} t_{av})(P_{id}R_{id} + P_{st}R_{st}) = (24 - \frac{30}{3600} 20.1)(50 \times 0.13 + 31 \times 0.87)$$

=797Wh

Calculation daily energy consumption

$E_d = 631 + 797 = 1{,}428$ Wh

This is 1.4 kWh per day[8].

[8] About 0.7p (0.7c) per trip!

6 A MORE ACCURATE CALCULATION

The figures given in ISO-Tables 2, 3 and 4 are based on the median values for the usage category obtained using statistical smoothing techniques. If the usage is discovered to be at the lower or higher end of a category then using the median value may be inaccurate.

Thus if the actual number of trips is not close to the median it is suggested that values could be obtained from the tables by interpolation or for more accuracy by using the graphs [4] from which these tables have been derived [5].

It may be necessary, for example, that in order to obtain credits under BREEAM a more accurate calculation is required (for example by means of simulations).

Suppose the installation in Example 1 had either 1,000 or 2,000 number of starts per day, instead of the median of 1,500 starts per day. These duties are at the extreme ends of the Usage Category 5.

What then are the values for average travel distance, average car load and the idle/standby time ratio?

Figure 1 shows a fuller presentation of the average distance travelled -v- number of starts.

Figure 2 shows a fuller presentation of average load transported -v- number of starts and rated load.

Figure 3 shows a fuller presentation of the ratios of running, idle and standby times.

With all other data remaining the same consider 1000 and 2000 starts per day. Carrying out the calculations Table 5 gives a comparison.

Table 5: Calculations using Figures 1 – 3

Number of starts per day	**1500**	**1000**	**2000**
Average travel distance	33% [from Table 2	44% [from Figure 1]	30% [from Figure 1]
Average car load	7.0% [from Table 3]	3.5% [from Figure 2]	12.5% [from Figure 2]
Load factor (k_L) [from $k_L = 1 - (\%Q \times 0.0164)$]	0.89	0.94	0.80
Idle/Standby time ratio	42/58 [from Table 4]	34/66 [from Figure 3]	45/55 [from Figure 3]
Daily running energy consumption	37.5 kW	35.2 kW	40.8 kW
Daily standing energy consumption	4.2 kW	4.3 kW	3.7 kW
Daily energy consumption	41.7 kW	39.5 kW	44.5 kW

The simple method proposed in ISO/DIS 25745-2 gives a daily energy consumption of 41.7 kW. If the extremes of Usage Category 5 are considered then the energy consumption ranges from 39.5 kW at the low end to 44.5 kW at the high end.

7 DISCUSSION

In observing Table 5 it can be seen that there is a smaller consumption for the smaller number of starts and a higher consumption for the larger number of starts. In this case they represent −5.5%/+6.7%. Thus in this case the accuracy of the median value is better than 10%.

It is worth noting that the average car load for the highest number of starts is still very low at 12.5%. This observation supports the concept that in off peak periods of time some of the lifts in a group should be shut down (in sequence to balance wear and tear) to ensure cars are loaded towards balance. This reduction of the number of lifts in service should however provide acceptable passenger waiting times at all times.

8 CONCLUSIONS

This paper has presented a method of calculating daily energy consumption following the proposals contained in the ISO/DIS/25745-2 [3]. This method is the most accurate method for general classification purposes so far proposed in the public domain (see review of the state of the art of energy estimation methods in [5]). It does involve obtaining values for a number of parameters on site, in a test tower or by computer modelling. The final value obtained is totally dependent on the value of the exact number of trips (n_d) being known from measurement or specification.

The simplified method using Equation 2 plus Equation 4 produces good results, but it is less accurate than using the graphs.

For practical purposes, the lift manufacturer can measure in a test tower all the travel distances appropriate to the product range in order to be able to provide values for the energy consumed for an ISO Reference Cycle (E_{rc}).

REFERENCES

[1] BS EN ISO 25745-1: 2012 *Energy performance of lifts, escalators and moving walks Part 1: Energy measurement and verification*

[2] CIBSE Guide D: 2010 *Transportation systems in buildings*.

[3] ISO/DIS 25745-2: 2013 *Energy performance of lifts, escalators and moving walks Part 2: Energy calculation and classification for lifts (elevators)*

[4] Lorente, A-M, Nunez, J.L & Barney G.C.: *Energy models for lifts*; 2nd Symposium on Lift and Escalator Technologies, 27 September 2012, The University of Northampton and WWW.ELEVATORWORLD.COM, April 2013.

[5] Lorente, A-M, doctorate thesis to be submitted to the University of Zaragoza entitled: *Life Cycle Analysis and Energy Modelling of Lifts*

ACKNOWLEDGEMENTS

ISO/TC178/WG10 for developing the method. The Task Group of WG10 for developing the load factor (k_L). The tables contained in the standard were developed by Ana Lorente [5] as part of her doctorate studies at the University of Zaragoza, Spain in support of the work of WG10 and are described in Reference 4.

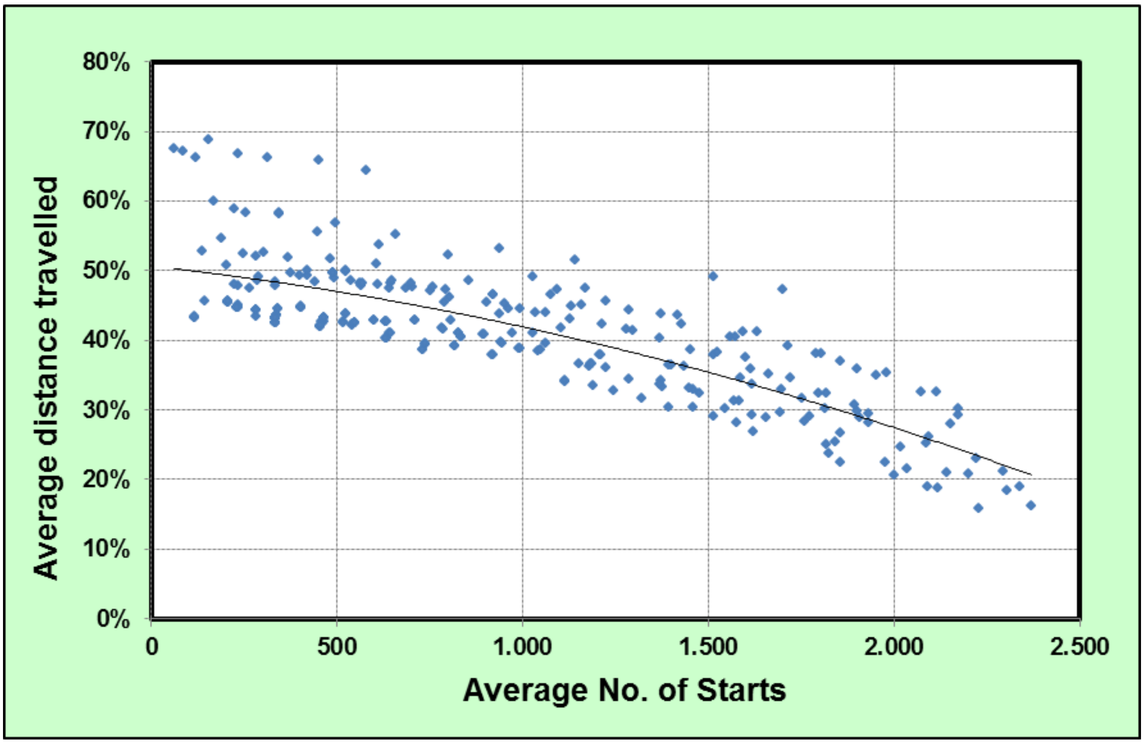

Figure 1: Average distance travelled -v- number of starts

Observe that as the number of starts increases the average distance travelled falls.

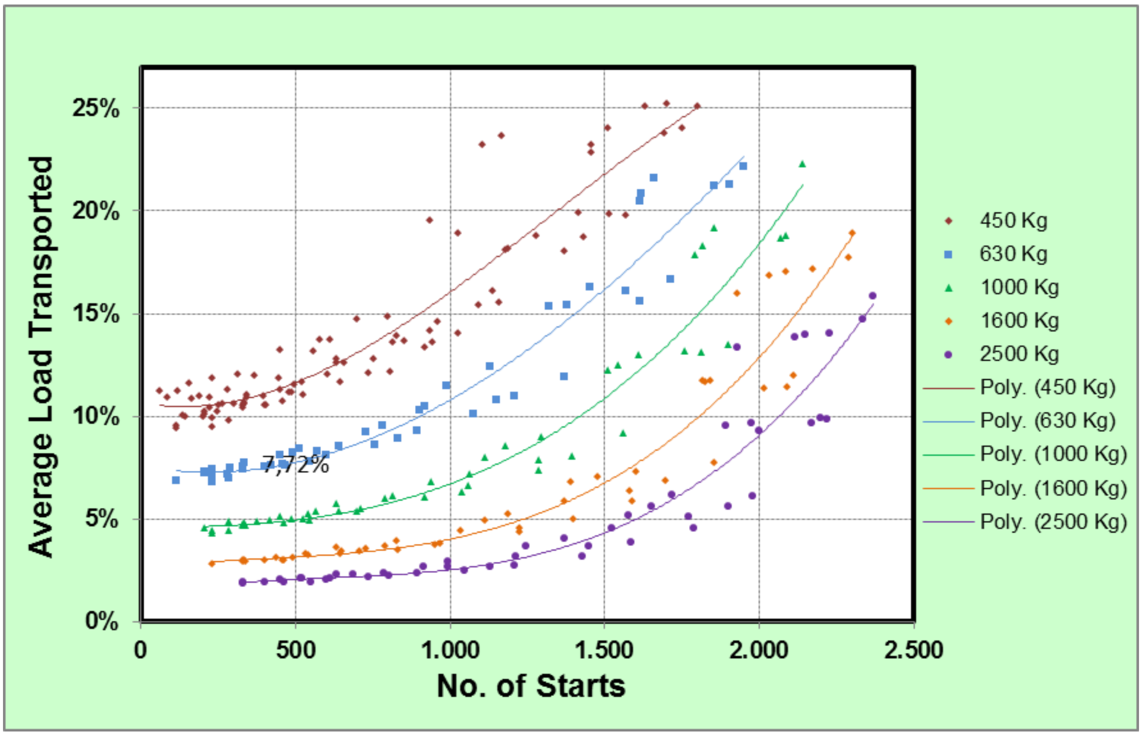

Figure 2: Average load transported -v- Number of starts for various rated loads

Observe that as the number of starts increases the average load increases.

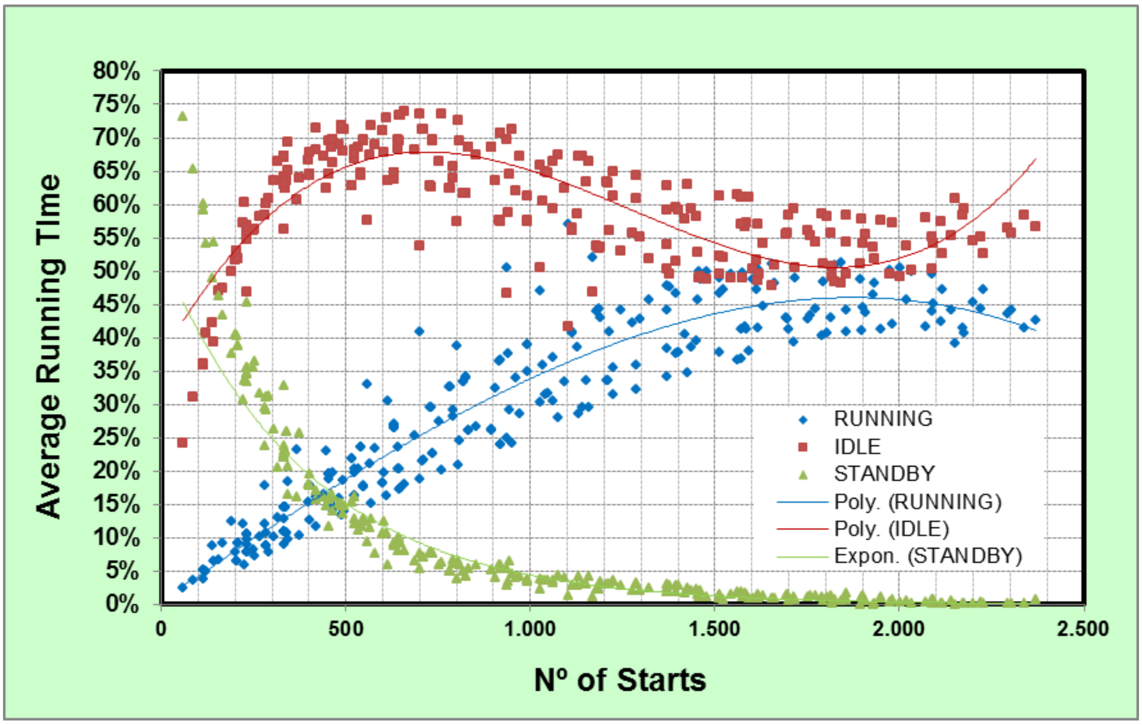

Figure 3: Ratios of running, idle and standby times.

The total running + idle + standby should equal 100%, but may not be exactly so owing to statistical variations. As the number of starts increase the standby falls towards zero leaving running and idle times as roughly equal components. The reason for the turnover at the highest number of starts is due to installation saturation in the face of exceptionally severe traffic demands.