CIBSE Guide D

Transportation systems in buildings

CIBSE

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Preface to the sixth edition

Transportation systems in buildings is, effectively, the first volume of the sixth edition of the Institution's *Guide*.

The first edition of what is now known as the *CIBSE Guide* was published in 1940 by the Institution of Heating and Ventilating Engineers. It was then known as the *Guide to Current Practice* and took the form of some 500 loose-leaf sheets held in a binder bearing the IHVE's insignia. This was reprinted as a bound volume in 1955. A fully revised second edition appeared in 1959 and this was superseded in 1965 by the third edition, the last to be published as a single volume. By the time of publication of the fourth edition, commencing in 1970, the contents of the *Guide* had expanded to such an extent that three bound volumes were required. Between 1972 and 1982, various sections were revised and published as separate booklets but, in response to criticism from members who could never be sure that their *Guide* was complete and up-to-date, it was decided to bring together all the revised sections into a new bound edition. This was published in three volumes between 1986 and 1988 as the fifth edition.

Such was the enthusiastic response to the publication of this edition, that the Institution's Technology Board decided that a rolling programme of revision should be implemented. The Board also required that the content of the *Guide* be greatly increased to reflect the ever-widening scope of work undertaken by CIBSE members. In seeking to meet this requirement, the Technical Publications Committee drew up a proposed list of contents which, it quickly became clear, could not be accommodated into three, or even four, new volumes. Consequently, it was decided that the *Guide* should be restructured into a series of volumes, each of which would deal in depth with a particular subject. These volumes, which together will constitute the sixth edition, will be introduced individually over the coming years to replace the fifth edition.

It is, perhaps, appropriate that the first volume of this new edition (identified as 'D' to avoid confusion with the fifth edition) should deal with a subject barely touched upon in previous versions of the *Guide*. Furthermore, *CIBSE Guide D: Transportation systems in buildings* is thought to be the first comprehensive publication dealing specifically with this important subject.

The establishment of the CIBSE Lift Group means that a mechanism is already in place to keep abreast of developments in this field and begin the work of updating this volume, in accordance with the policy for a rolling programme of revision.

This volume has been produced by an enthusiastic team which combined the expertise and experience of building services engineers and specialists and practitioners from the lift and escalator industry. The members of this team have dedicated vast amounts of time to the preparation of this volume with the objective of producing a useful tool for those responsible for both the design and operation of transportation systems within buildings. These include architects, building services engineers, quantity surveyors, installation and maintenance contractors, facilities managers plus, of course, building owners and occupiers.

As chairman of the committee responsible for initiating the sixth edition of the *CIBSE Guide*, I should like to take this opportunity to pay a sincere tribute, on behalf of both the Council of the Institution and its members, to all those who have worked to prepare this and subsequent volumes of the *Guide* and who, in doing so, have sacrificed so much of their professional and leisure time.

D J Stokoe
Chairman, Technical Publications Committee

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1 Introduction

1.1 Origins of transportation systems in buildings

Hand powered lifts or hoists in various forms have been in use since the days of the pyramid constructors in Egypt (c2600 BC) and it is claimed that, in China, hand powered winches were used to draw water as far back as 2200 BC. In 236 BC, in ancient Greece, Archimedes developed a lifting device in which the hoisting ropes were coiled around a winding drum. The Roman Emperor Titus used elevators to raise the gladiators and wild animals to the level of the arena of the newly-built Coliseum in 80 AD. Throughout medieval times, lifts and hoists were commonly used in the construction of castles, churches and monasteries.

The development of steel-framed buildings in the USA enabled buildings to be constructed to heights impossible with conventional foundations. This led to a need for transportation systems capable of conveying people to these heights in safety and comfort. In 1853, Harper's Magazine remarked on 'the introduction of a steam elevator by which an indolent or fatigued or aristocratic person may be borne up to the third, fourth or fifth floor.'

That same year, Elisha Otis established a company to manufacture hoists and, soon after, was able to demonstrate his new safety device at the Crystal Palace Exposition in New York City which ensured the widespread acceptance of vertical transportation systems in tall buildings. His famous words 'All safe, gentlemen, all safe!', spoken from the lift platform after the suspension ropes had been severed, are an important part of engineering history. Today the lift has the best safety record of any form of transportation and its installation in buildings is accepted as essential, especially to enable the elderly and people with disabilities to gain access to all kinds of buildings.

Many technological advances have occurred over the 14 decades since Elisha Otis' dramatic demonstration, but the basic components of a typical lift installation remain the same (machine, gearing and sheave, suspension, guide shoes and guide rails, safety gear, car and counterweight) and would still be recognisable to Otis. He would, however, identify important advances in the performance of lift systems, particularly in drive control, traffic control and signalling, monitoring and management systems, and in engineering and traffic design techniques. All these advances owe their significance to the use of the modern digital microcomputer and its associated software systems. Such advances are amply illustrated by the Sunshine Building in Tokyo which is equipped with lifts operating at speeds of 10.0 m/s.

1.2 Purpose of *Guide D*

The purpose of *CIBSE Guide D: Transportation systems in buildings* is to provide guidance to practitioners involved in such systems. This *Guide* should also be of interest to architects, surveyors and building managers who, while not directly concerned with the design or installation of lifts and escalators, need to understand the advice offered to them by specialists. Not least, the *Guide* should be of value to students embarking on a career in mechanical, electrical or building services engineering and those already practising in these disciplines who wish to enhance their knowledge through a programme of continuing professional development.

1.3 Contents of *Guide D*

The design of any lift or escalator system must commence with a consideration of the traffic flows through the building for which the system is intended. The relevant factors, along with guidance on the location and arrangement of lifts and escalators within buildings, are discussed in section 2. The assessment of demand is considered in section 3.

Section 4 presents on overview of the various types of transportation system and identifies any special considerations which need to be borne in mind when dealing with certain kinds of installation. Firefighting lifts and escape lifts for the disabled are particularly important categories and, for this reason, these are treated separately in section 5.

The principal components of lifts, including both electric traction and hydraulic drives, are described in section 6. Control techniques, both computer- and relay-based systems, are considered in section 7 which also considers the control of door operators.

Electrical systems and power supplies are discussed in section 8. This section also considers the problems of harmonic distortion and interference.

Human comfort, for both passenger and maintenance staff, and the environment conditions in the lift car and machine room are dealt with in section 9. Included as an appendix to this section is a typical lift which illustrates how the required environmental parameters may be specified.

Remote monitoring techniques and the integration of the lift controls into building management systems (BMS) are considered in section 10.

Section 11 considers computer calculation techniques and shows the range of values that can result when various programs are applied to a specimen design problem.

The widespread adoption of formal quality assurance schemes will be of increasing benefit both to the lift and escalator industry and to the users of its products. Quality assurance schemes are considered in section 12.

Typically, lift installations require modernisation after 15–20 years of service. Section 13 suggests a phased approach which will minimise the disruption to service during such modernisation.

Section 14 takes the form of an extensive glossary of terms. This is not limited to the terms used within this *Guide* but includes definitions of many the terms likely to be encountered when dealing with lift and escalator systems. The CIBSE is indebted to the International Association of Elevator Engineers for permission to reproduce this valuable glossary.

1.4 Other sources of information

It is hoped that *CIBSE Guide D: Transportation systems in buildings* will provide an invaluable reference source for those involved in the design, installation, commissioning, operation and maintenance of transportation systems in buildings. However it cannot, and does not claim to be exhaustive. It contains many references to other sources of information, particularly British Standards, which should be carefully consulted in conjunction with this *Guide*.

2 Interior circulation principles

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Acknowledgements

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2 Interior circulation principles

2.1 Introduction

The circulation of people† within a building is a complicated activity. People may move vertically or horizontally and either naturally or with mechanical assistance.

The circulation of people in a building must be designed to consider all possible routes of movement. These routes should be clearly marked so that they are obvious to all users. It is essential that patterns of circulation are rational, that incompatible types of circulation do not coincide and that the movement of people and goods is minimised. The design of portals (i.e. entrances, doorways, gates etc.), corridors, stairs and mechanical transportation systems (moving walkways, moving ramps, escalators, lifts) must be co-ordinated to ensure:

— free flow of people, goods and vehicles

— minimal wastage of space

— prevention of bottlenecks.

It is important to size each facility. Thus the handling capacities of corridors which lead to stairs or lifts should be adequate for their anticipated load.

Since the theory of interior circulation is not well developed much of the following is based upon observation and experience. Reasons are given so that the results can be modified if new evidence comes to hand or opinions change. Fuller expositions and extensive references can be found in Fruin[1] and Tregenza[2]. The interior design may be affected by other regulations such as fire and safety codes and these must be taken into account. Design planning recommendations are given for lifts in Section four of *BS 5655: Part 6*[3] and *ISO 4190-6*[4], but these should be used with great care as the information presented is elementary and oversimplified, and may lead to incorrect sizing.

2.2 Human factors

2.2.1 Human personal space

Humans value personal space. This is measured by a 'buffer zone' around each individual. The size of the buffer zone varies according to an individual's culture, age, status, sex, physical and mental handicaps, etc. For example, it has been observed that individual female subjects are comfortable with a personal buffer zone of 0.5 m^2 (0.8 m diameter circle) and individual male subjects with a personal buffer zone of 0.8 m^2 (1.0 m diameter circle). To help visualise these areas, a woman's umbrella occupies an area of approximately 0.5 m^2 and a man's umbrella approximately 0.9 m^2.

These factors must be borne in mind when designing pedestrian waiting areas. Recommended densities, when considering bulk queues (i.e. people waiting for an event), are given in Table 2.1.

When considering linear queues (i.e. people 'waiting in a line' for a service) assume 2 persons per metre length of space. If a barrier is used, a queue can be restrained to the barrier width which should be set to no less than 600 mm. For unrestrained queues assume 1.5 m width.

Table 2.1 Recommended densities of people in bulk queues

Level of comfort	Density (person/m^2)
Desirable	0.4
Comfortable	1.0
Dense	2.0
Crowded	3.0
Very crowded	4.0‡

‡ Possible only in confined spaces

2.2.2 Human physical dimensions

The physical dimensions of the human body vary widely, but to allow for all circumstances of individuals (heavy clothing, body sway, etc.), it is recommended that the body template be considered as an ellipse of dimensions 600 mm by 450 mm and occupying 0.21 m^2. This is a maximum value and can be used where pedestrians are not standing in a confined space.

The recommended design density, when sizing a lift car can be smaller as passengers are constrained and some allowance can be made for averaging. European Standard *EN 81*[5] uses a complicated formula which allows 0.1 m^2 plus 0.2 m^2 per person in a car with a capacity of up to 6 persons, 0.15 m^2 per person in a car with a capacity of up to 20 persons, and 0.12 m^2 per person thereafter. These values require passengers to be very crowded in a large car. It has been observed that lift cars do not fill to their rated (person) loads. It is recommended that a uniform figure of 0.2 m^2 be assumed when sizing a lift car in order to carry out a traffic design (see section 3.6.1).

† Within this section, people are generally referred to as pedestrians when moving on foot and as passengers when mechanically transported.

2.3 Circulation factors

2.3.1 Corridor handling capacity

The capacity (in persons per minute) of a straight corridor is given by:

$$C_p = 60\, v\, D\, W \qquad (2.1)$$

where C_p is the corridor handling capacity (person/min), v is average pedestrian speed on the horizontal (m/s), D is the average pedestrian density (person/m^2), W is the effective corridor width (m).

There are a number of qualifications to this empirical relationship. Pedestrian speed and density are not independent. For concentrations below 0.3 person/m^2 pedestrians can walk freely (i.e. free flow design). Above 0.5 person/m^2 there is an approximately linear decrease of average walking speed up to about 3.0 person/m^2, when walking is reduced to a shuffle. The throughput peaks at a density of about 1.4 person/m^2 (i.e. full flow design).

Walking speeds vary systematically with:

— type of person (age, sex, grouping, purpose)
— ability (fitness, handicap)
— flow direction
— gradient
— air temperature
— floor finish, etc.

Within each group there will be variations in average speed. Table 2.2 provides guidance for typical average values for pedestrian flows for different groups of pedestrians. The table shows the typical pedestrian horizontal speeds (m/s) and pedestrian flows in persons per minute (person/min). The flows assume a corridor width of one metre.

Table 2.2 Possible pedestrian flows with grouping

Type of traffic	Horizontal speed and pedestrian flow rate for stated type of design flow			
	Free flow design (0.3 person/m^2)		Full flow design (1.4 person/m^2)	
	Speed (m/s)	Flow rate (person/min)	Speed (m/s)	Flow rate (person/min)
Commuters, working persons	1.5	27	1.0	84
Individual shoppers	1.3	23	0.8	67
Family groups, tourists	1.0	18	0.6	50
School children	1.1–1.8	18–32	0.7–1.1	59–92

The width of corridor is not specified, but must be at least 900 mm and is assumed to be 1 m. Equation 2.1 allows for the flow rate to increase or decrease as the corridor width increases or decreases. This factor must be used with care as some changes in corridor width will have little or no effect. Table 2.3 presents the minimum widths of straight corridors, which have been found suitable for different purposes.

Table 2.3 Minimum corridor widths

Type of traffic	Minimum corridor width (m)
One way traffic flow	1.0
Two way traffic flow	2.0
Two men abreast	1.2
Man with bag	1.0
Porter with trolley	1.0
Woman with pram	0.8
Woman with pram with child alongside	1.2
Man on crutches	0.9
Wheelchair	0.8†

† Wheeled vehicles, especially if very long, require extra width at junctions

Only unrestricted routes allow traffic to flow freely and corridors are rarely free of obstructions. Table 2.4 provides a guide to the effect of some obstructions. For example, the effective width of a 2 m wide corridor is reduced to 1 m, if persons are seated in a row along one side of the corridor.

Table 2.4 Reductions in corridor width

Obstruction	Reduction in width (m)
Ordered queue	0.6
Unordered single queue	1.2–1.5
Row of seated persons	1.0
Coin operated machine:	
— one person	0.6
— queue	1.0
Person waiting with bag	0.6
Window shoppers	0.5–0.8
Small fire appliance	0.2–0.4
Wall-mounted radiator	0.2
Rough or dirty wall surface	0.2

2.3.2 Effect of portals

A portal (i.e. gate, door, entrance, turnstile, etc.) forms a division between two areas for reasons of privacy, security, access control, etc. Portals restrict corridor width. The same general conditions apply as for corridors but flow rates are reduced. Table 2.5 shows the possible flow rates (person/min) through an opening of 1 m.

Table 2.5 Portal handling capacities

Portal type	Flow (person/min)
Gateway	60–110
Clear opening	60–110
Swing door	40–60
Swing door (fastened back)	60–90
Revolving door	25–35
Waist-high turnstile:	
— free admission	40–60
— cashier	12–18
— single coin operation	25–50

2.3.3 Stairway handling capacity

Stairways impose a more stylised form of movement on pedestrians, allowing higher densities than are possible on level floors. For free movement while walking on a level floor a pedestrian requires some 2.3 m^2, whereas a stair walker needs only to perceive two vacant treads ahead (and room for body sway) and thus occupies only about 0.7 m^2. Therefore free flow design is possible at 0.6 person/m^2 and full flow design is possible at 2.0 person/m^2. The speed along the slope is about half of that on a level surface, but some of this reduction in capacity is recovered by the increased densities possible.

Pedestrian speed is very much dependent on the speed of the slowest stair walker, owing to the difficulty of overtaking in crowded conditions. Although speeds might be expected to be higher in the down direction, they are reduced by the need for greater care. This results in similar speeds in both directions. Speed is also affected by the angle of inclination and step riser height. A rule of thumb has been to match the average adult stride (on a stairway) of 0.6 m with the sum of twice the riser height plus the tread. This results in a range of riser heights of 100 mm to 180 mm and treads of 360 mm to 280 mm, which gives possible inclinations from 15° to 33°. An efficient inclination has been found to be 27°. An empirical formula for stair capacity is:

$$C_p = 0.83\,(60\, v\, D\, W) \qquad (2.2)$$

where C_p is the corridor handling capacity (person/min), v is average pedestrian speed on the horizontal (m/s), D is the average pedestrian density (person/m^2), W is the effective corridor width (m).

Table 2.6 provides guidance for pedestrian stair flows for each 1 m width of stairway. It shows the typical pedestrian stairway speeds (m/s) along the slope and pedestrian flow rates (person/min) for each 1 m width of stairway.

Table 2.6 Stairway handling capacity

Type of traffic	Horizontal speed and pedestrian flow rate for stated type of design flow			
	Free flow design (0.3 person/m^2)		Full flow design (1.4 person/m^2)	
	Speed (m/s)	Flow rate (person/min)	Speed (m/s)	Flow rate (person/min)
Young/middle-aged men	0.9	27	0.6	60
Young/middle-aged women	0.7	21	0.6	60
Elderly people, family groups	0.5	15	0.4	40

2.3.4 Escalator handling capacity

Escalators provide a mechanical means of continuously moving pedestrians from one level to another. A number of factors affect their handling capacity:

— Speed along the horizontal (i.e. in the direction of movement of the steps): commonly 0.5 and 0.65 m/s. Most escalators are run at one speed only, although some heavy duty escalators offer the facility of switching to a higher speed during heavy traffic. Other speeds are available. For example speeds of 0.75 m/s are used on the London Underground and speeds of 0.9–1.0 m/s are used with some deep systems in Russia and Ukraine.
— Step widths (i.e. hip width): step widths of 600, 800 and 1000 mm are available, the latter allowing two columns of passengers.
— Inclination: usually 30°, but sometimes 27°. An inclination of 35° is possible, provided the maximum speed is less than 0.5 m/s and the rise is less than 6 m.
— Boarding and alighting areas: to encourage efficient access it is recommended that at least one and one third flat steps (light duty) to two and one third flat steps (heavy duty) be provided for passengers boarding and alighting an escalator. Where possible three flat steps are desirable to ease the flow on and off the units and to assist handicapped individuals. Steps are usually 400 mm deep and an average boarding/alighting stride can be assumed to be 750 mm.

Escalator handling capacity is given by:

$$C_p = 60\, v\, k\, s \qquad (2.3)$$

where C_p is the escalator handling capacity (person/min), v is the speed along the flat (m/s), k is the average density (people/step), s is number of steps (steps/m)

For the case of 2.5 steps/m:

$$C_p = 150\,v\,k \qquad (2.4)$$

Table 2.7 gives handling capacity values for a theoretical occupancy density (k) of two persons per 1000 mm step (i.e. k = 2.0), three persons per two 800 mm steps (i.e. k = 1.5) and one person per 600 mm step (i.e. k = 1.0). The observed density is about half this value, giving practical handling capacities of about half the tabulated values.

The common UK practice of one stationary column and one walking column does not increase the throughput, because more personal space is required, but it does decrease an individual's travelling time. Also, higher escalator speeds will not necessarily increase throughput as passengers may experience difficulties in boarding or alighting at the higher speeds.

Table 2.7 Maximum escalator handling capacities

Horizontal speed (m/s)	Maximum handling capacity (person/min) for stated step width (mm)		
	1000	800	600
0.50	150	113	75
0.65	195	146	98
0.75	225	169	113

2.3.5 Handling capacity of moving walkways and ramps

Walkways have an inclination of 0° and ramps have inclinations in the range 3° to 12°. As the passengers are not constrained by steps, as they are on an escalator, a theoretical passenger density of 4.3 person/m² might be possible but a nominal density of 2.2 person/m² is more likely. The handling capacity of both types of conveyor is given by equation 2.1. Several walkway speeds are used but ramp speeds are determined by the inclination. Again, speeds are taken in the direction of movement, i.e. the horizontal plane. Commonly available widths are 800 mm, 1000 mm and 1400 mm. Table 2.8 indicates the nominal capacity for several commonly available conveyors.

2.3.6 Handling capacity of lifts

The method for sizing lift systems is given in section 3.

In circulation design it is important to bear in mind that lifts cannot handle the traffic volumes handled by other facilities. They have a considerable throttling effect on pedestrian movement. For example, the most efficient 8-car group comprising 21-person capacity cars serving 14 floors can provide a handling capacity of only 50 person/min. This is less than that provided by a flight of

Table 2.8 Handling capacities of moving walkways and ramps for nominal density of 2.2 person/m²

Inclination (degree)	Speed (m/s)	Nominal handling capacity (person/min) for stated width (mm)		
		800	1000	1400
0	0.50	53	66	92
0	0.63	66	83	116
0	0.75	79	99	139
5	0.70	74	92	–
10	0.65	69	86	–
12	0.50	53	66	–

stairs. A 3-car group comprising 10-person cars serving 8 floors can manage only 16 person/min. Thus for bulk transit systems the use of escalators is highly recommended. Fortunately the high volumes found in bulk transit systems do not occur when populating or emptying a building but, as will be seen in section 3, care must be taken in sizing a lift system for the worst cases.

Observation lifts are sometimes installed as a feature to provide visual impact in retail and hotel complexes. They contribute to the circulation aspects of a building but at a lower handling capacity to take account of the fact that passengers often ride the lifts simply to enjoy the view (see section 4.3).

2.3.7 Comparison of handling capacities

The handling capacities of the circulation modes are compared in Table 2.9. The values given are rounded for convenience, and apply to average groups of people and facilities.

Table 2.9 Comparison of handling capacities for various types of circulation

Circulatory mode	Item†	Handling capacity (person/min)	Density (person/m²)
Horizontal	Corridor	80	1.4
	Portal	60	1.4
	Conveyor	120	2.0
Incline	Stairs	60	2.0
	Ramp	85	2.2
	Escalator	90	2.5‡
Vertical	Lift	50¶	5.0

† With the exception of lifts, a width of 1 m is assumed.
‡ Assumes 1 person per step.
¶ See section 2.3.6.

Example 2.1

Consider a commuter railway station with a main flow of 160 person/min and a counterflow of 80 person/min. The concourse is entered through swing doors from the street and via stairs from the platform area. Various facilities are situated in the concourse as shown in Figure 2.1. Determine the number of swing doors and the width of stairway required and a possible floor plan.

Both the doors and stairway must handle 240 person/min. Thus there should be at least four 1 m doors and at least 4 m of stairway. The stairway should be divided centrally by a barrier rail to impose restrictions on the pedestrians' movements.

It is necessary to provide at least 3 m of clear corridor through the concourse. This can be achieved by the plan shown in Figure 2.2.

2.4 Location and arrangement of transportation facilities

2.4.1 General

The location and arrangement of corridors, portals, moving walkways and ramps, escalators and lifts should take account of the proximity of entrances and stairs and the distribution of the occupants in the building. The main principles are to minimise the movements of people and goods, and to prevent bottlenecks.

Ideally all circulation activities should be centralised. Sometimes the access points in buildings prevent this and in such cases it may be better for occupants to walk to the centre of a building to reach the stairs and lifts, since usage during the day may outweigh the comparative inconvenience during arrival and departure. The maximum distance to a lift or stair should not exceed 60 m, with 45 m being preferred. Escape routes are generally nearer, but are not necessarily part of the normally used circulatory routes.

The use of long traffic routes at the ground floor are undesirable for several reasons:

— In buildings to which the public have access visitors should be able to make their way quickly to an upper floor, where their intended destination is clearly marked. Visitors who walk about on the ground floor, with only a vague idea where they are going, greatly restrict circulation.

— Circulation on the ground floor includes the whole of the flow into the building, normally requiring a special space allocation. On the upper floors the load is distributed and should be catered for without difficulty using the normal circulation arrangements.

— The access of large numbers of people to large areas of the ground floor of a building poses a substantial security risk.

Stairs and escalators should not lead directly off corridors, but be buffered by landing areas so that the vertical and horizontal modes of circulation can merge smoothly.

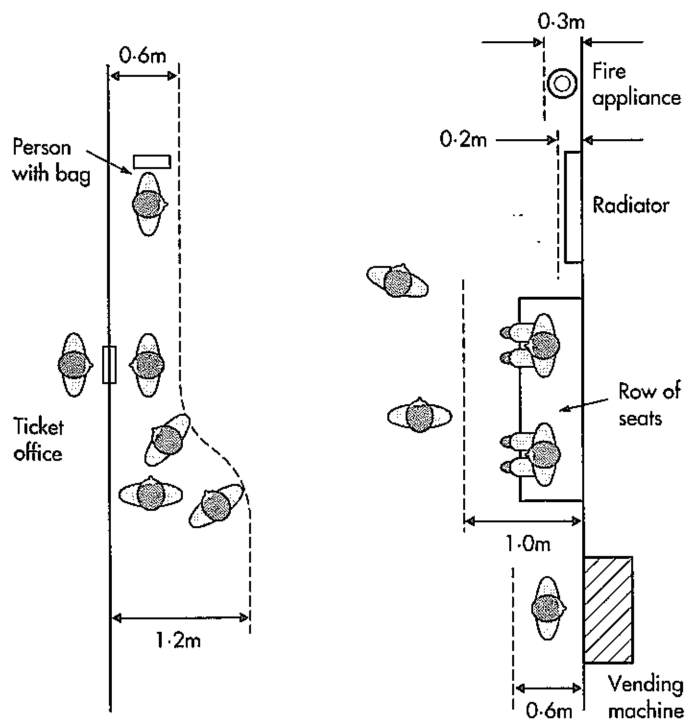

Figure 2.1 Example 2.1: facilities to be provided

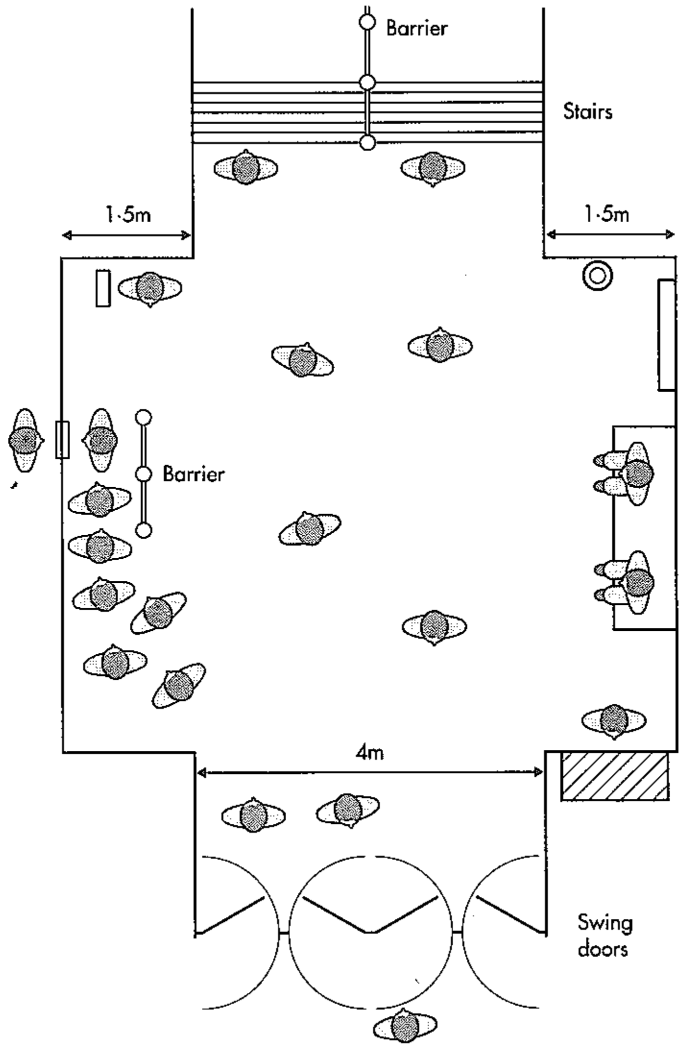

Figure 2.2 Example 2.1: a possible design solution

If the use of stairs for short journeys to or from adjacent floors is to be encouraged, the stairs should be clearly visible, adequately signed and encountered before the lifts.

2.4.2 Location of escalators

The locations of escalators require the same conditions as stairs but escalators do occupy more space. Typical arrangements are shown in Figure 2.3.

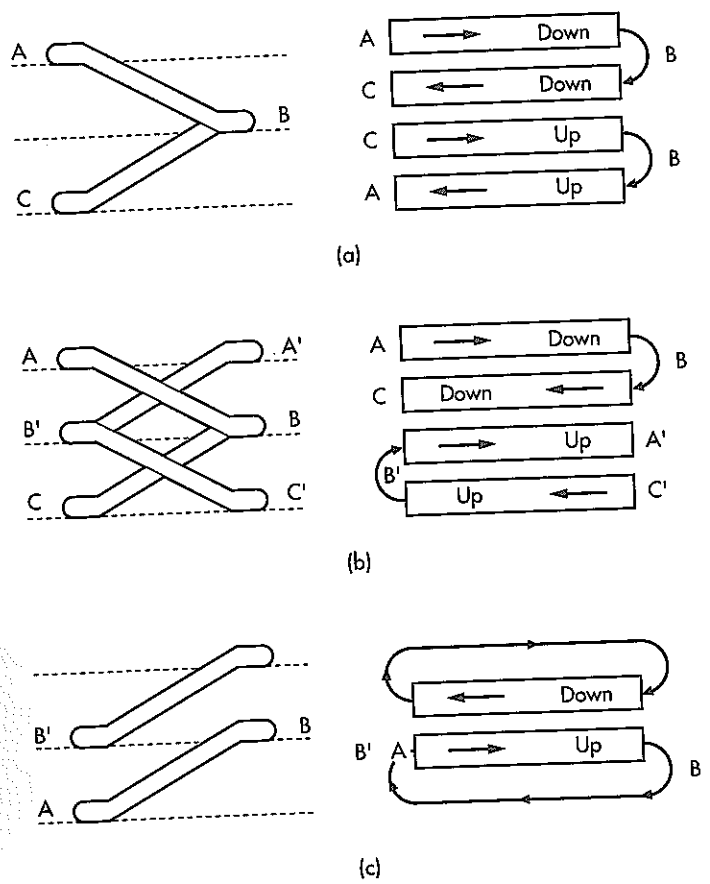

Figure 2.3 Arrangements for escalators; (a) parallel, (b) cross-over, (c) walk around

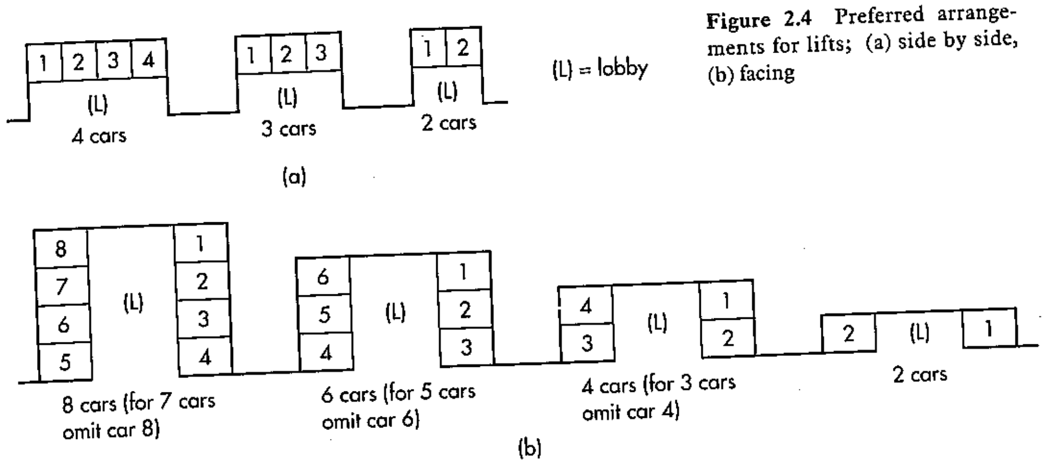

Figure 2.4 Preferred arrangements for lifts; (a) side by side, (b) facing

2.4.3 Location of lifts

Lifts should always be placed together rather than spread around the building. This will provide a better service, mitigate against the failure of one car and lead to improved traffic control.

Lift lobbies should not be part of a through route, but have their own separate waiting area. The preferred arrangements of two to eight lifts are shown in Figure 2.4. Eight is considered to be the maximum number of lifts that allows waiting passengers to detect the arrival of a car easily, to walk to it and to enter it in a reasonable time.

Observation lifts may be installed as a group or part of a group and care should be taken with their location, see section 4.3.

References

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2 Tregenza P *The design of interior circulation: people and buildings* (London: Crosby Lockwood) (1976)

3 *BS 5655: Lifts and service lifts: Part 6: Code of practice for selection and installation* (London: British Standards Institution) (1990)

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3 Planning and selection of equipment and performance of transportation systems

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3 Planning and selection of equipment and performance of transportation systems

3.1 Introduction

3.1.1 General

The transportation capacity of the lift group in a building is a major factor in the success or failure of a building as a place to work, live or receive a service. Like toilets, lifts should be available and easy to use without a second thought. Unfortunately this is not always the case and speculative building often results in the installation of an imperfect lift system.

The planning and selection of transportation equipment is a very involved subject. Although the basic calculations are relatively simple the theory on which they are based is complex. The results obtained need to be tempered with a great deal of working experience of existing buildings, in order to ensure satisfactory design results.

This section provides the means of calculation and analysis for the planning and selection of transportation equipment (mainly lifts) and the procedures to determine their likely performance. The morning peak of traffic as a building's occupants arrive for work (the up-peak traffic condition) is examined in detail because it lends itself to analytical techniques. The other two major conditions (down-peak and interfloor) are analysed and recommendations given.

Readers unfamiliar with this subject might benefit from first studying the design example given in section 3.12, in order to gain a feel for the design and planning processes.

The various terms encountered are generally explained in the text but fuller definitions are to be found in the glossary, section 13. All the symbols used are given below for ease of reference.

3.1.2 Symbols and abbreviations

A_r	average passenger arrival rate (person/s)
AWT	up-peak average passenger waiting time (s)
CC	contract (rated) capacity (persons)
D_d	percentage down-peak demand (%)
d_f	average interfloor height (m)
d_H	distance to reach highest reversal floor (m)
D_i	percentage interfloor demand (%)
DNAWT	down-peak passenger average waiting time (s)
DNPINT	down-peak interval (s)
DNSTPS	number of down-peak stops
H	average highest reversal floor
H_e	distance of travel to express zone terminal (m)
IFAWT	interfloor passenger average waiting time (s)
INT	average interval with defined car load (s)
L	number of lifts
MT	main terminal
N	number of served floors above MT
P	average number of passengers
%POP	percentage population (%)
RTT	average round trip time (s)
S	average number of stops
T	floor-to-floor cycle time (s)
t_c	door closing time (s)
$t_{f(1)}$	single floor flight time (s)
$t_{f(n)}$	time to jump n floors (s)
t_l	passenger loading time (s)
t_o	door opening time (s)
t_p	average passenger transfer time (entry or exit) (s)
t_s	time consumed when making a stop (s)
t_u	passenger unloading time (s)
t_v	time to transit two adjacent floors at contract (rated) speed (s)
U	effective building population
UPPHC	average up-peak handling capacity (person/5 min)
UPPINT	average up-peak interval (s)
UPPSTPS	number of up-peak stops
v	contract (rated) speed (m/s)

3.2 Sizing of lift systems

3.2.1 Review of traffic design

The problem in sizing lift systems is to match the demands for transportation from the building's occupants with the handling capacity of the installed lift system. This procedure should also result in an economic solution.

By the 1970s, a recognised method of calculation had evolved, for the up-peak traffic sizing, based on the mathematical determination of average highest reversal floor (H) by Schroeder[1], average number of stops (S) by Basset Jones[2] and average number of passengers (P).

The formulae by Barney and Dos Santos[3] for the calculation of the passenger handling performance of lift systems are now universally accepted. Lift makers are able to use tables applicable to their product range, based on these formulae, to estimate round trip times, interval, handling capacity, etc.

Digital computer calculation and simulation packages have now been developed, which allow other traffic conditions to be examined. These computer techniques utilise proven mathematical techniques.

3.2.2 Data sets

The calculation of lift performance depends on three data sets concerning the building, the lift and the passengers.

3.2.2.1 Building data set

The building data set comprises the following:

(*a*) number of floors

(*b*) interfloor distance.

Both items (*a*) and (*b*) are fixed.

3.2.2.2 Lift system data set

The lift system data set comprises the following:

(*a*) number of cars

(*b*) contract capacity (rated capacity)

(*c*) contract speed (rated speed)

(*d*) flight times between floors

(*e*) door opening times

(*f*) door closing times

(*g*) traffic control system.

Items (*a*) and (*b*) are variables, to meet the required passenger traffic demands and the quality of service. Items (*c*) to (*g*) can be established from the lift manufacturer. The effect of (*g*) cannot be analysed mathematically and may only be assessed empirically.

3.2.2.3 Passenger data set

The passenger data set comprises the following:

(*a*) number of passengers boarding from specific floors

(*b*) number of passengers alighting at specific floors

(*c*) traffic mode, i.e. unidirectional or multidirectional

(*d*) transfer times for passengers entering and leaving cars

(*e*) passenger actions.

Items (*a*) and (*b*) are dependent on floor populations. It is these two items which determine the level of duty for a lift system i.e. the number of starts an hour it will be required to make. Items (*c*) and (*d*) are dependent on human behaviour and are not easily predictable. Item (*e*) is included to cover passenger misbehaviour (door holding, excess button pushing etc.). This data set is the least well defined and is subject to considerable error in its estimation.

3.3 Assessment of demand

3.3.1 General

The difficulty in planning a lift installation is not in calculating its probable performance, but in estimating the likely passenger demand. Quite often the building has yet to be built and estimates have to be based on the experience gained with previous similar structures. Existing buildings can be surveyed, by observation, or by means of an attached data logger, to determine the current activity. However, even this is prone to error, as the building's population may have adapted to poor (or good) lift performance. It is essential, therefore, that all the parties involved in the planning of a lift installation have a clear understanding of the basis for the planning. For example it is important that the architect or planner establishes the lift system required at a very early stage and not after the rest of the building has been designed, as often happens.

It is important to remember that the distribution and size of the population of any large building changes regularly. Thus a tightly planned design may prove inadequate once a building has been occupied for a year or more. To understand the effect of these changes on a design, it is essential to document the criteria and decisions taken at all stages of a design.

There are two key factors affecting the demand that a building's occupants will make on a lift system: the quantity of service and the quality of service. The quantity of service factor, i.e. how many people will use the lift system over a defined period of time, is represented by the handling capacity. The quality of service factor, i.e. how well must the lift system deal with its passengers, is represented by passenger waiting time. Both factors are interrelated. Both factors depend amongst other things on: the type of building and its use and the type of occupier. This makes the design task very difficult for buildings of a speculative nature.

The following sections make recommendations to ease the design task by looking at traffic patterns, building populations, the likely demand on the lift installation and the quality of service factor. The analysis is mainly relevant to commercial buildings.

3.3.2 Traffic patterns

Figure 3.1 illustrates a possible traffic pattern in an office building. It shows the number of up-hall calls and down-hall calls registered during the working day. In practice this pattern may not be observed exactly as shown, as many companies have adopted a 'flexitime' attendance regime. It does, however, serve as a model for discussion.

At the start of the day there is a larger than average number of up-hall calls. This is due to the building's occupants arriving to start work. This traffic pattern is called the morning up-peak. (See section 13 for further definitions of traffic terms.)

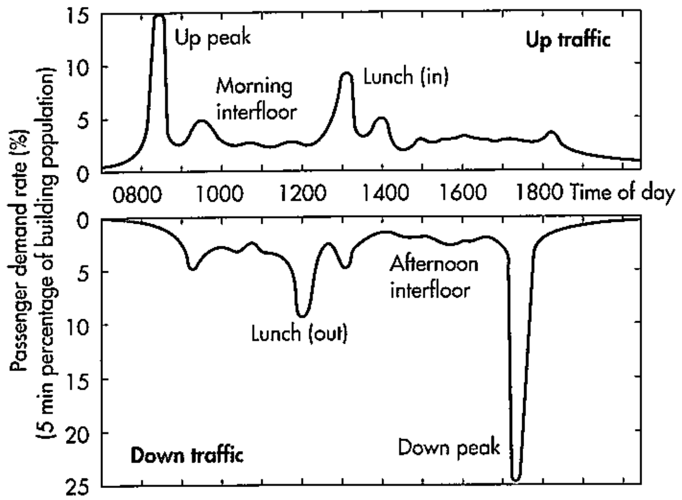

Figure 3.1 Passenger demand rate for an office building

Late in the day there is a larger than average number of down-hall calls. These are due to the building's population leaving the building at the end of the working day. This traffic pattern is called the evening down-peak.

In the middle of the day there are two separate sets of up-peaks and two down-peaks. This represents a situation where the occupants of the building take two distinct lunch periods (i.e. 12.00 to 13.00 and 13.00 to 14.00). This pattern is sometimes called two-way traffic.

During the rest of the day the numbers of up- and down-hall calls are similar in size and over a period are equal. This traffic pattern is called interfloor traffic, sometimes qualified as balanced interfloor traffic.

Figure 3.2 reveals that the up-peak traffic profile is slow to rise and quick to fall. The lift installation must be able to handle the peak, if a satisfactory service is to be provided. Industry practice is to size a lift installation to handle the number of passengers requesting service during the heaviest five minutes of the up-peak traffic condition. This is a sound recommendation. To size the lift system to handle the actual peak would require too large a system, which would be very expensive and much of the equipment would be under-utilised during large periods of the working day. Conversely, to use a 30-minute handling capacity would result in a totally inadequate installation, not only for up-peak traffic but also for the other traffic conditions.

Figure 3.2 also illustrates the down-peak traffic profile. This is somewhat larger in size and longer in duration than the up-peak profile. Fortunately a lift system can be shown to possess 50% more handling capacity during down-peak than during up-peak. This is because during down-peak a lift car fills at three, four or five floors and then makes an express run to the main terminal. This reduction in the number of stops results in a shorter round trip time and hence a greater handling capacity during down-peak.

Traffic conditions may be summarised as follows:

— the duration of the up-peak traffic condition is about 5 minutes

— the duration of the down-peak condition is about 10 minutes

— the two-way traffic condition may exist for one to two hours dependent on the arrangements for the midday break.

The interfloor traffic condition exists for most of the working day and therefore is very important.

If the up-peak traffic pattern is sized correctly, then generally all other traffic patterns will be adequately served. There are exceptions such as in hotels at meal times, hospitals at visiting times, buildings with trading floors which open at specified times (e.g. insurance and stock markets).

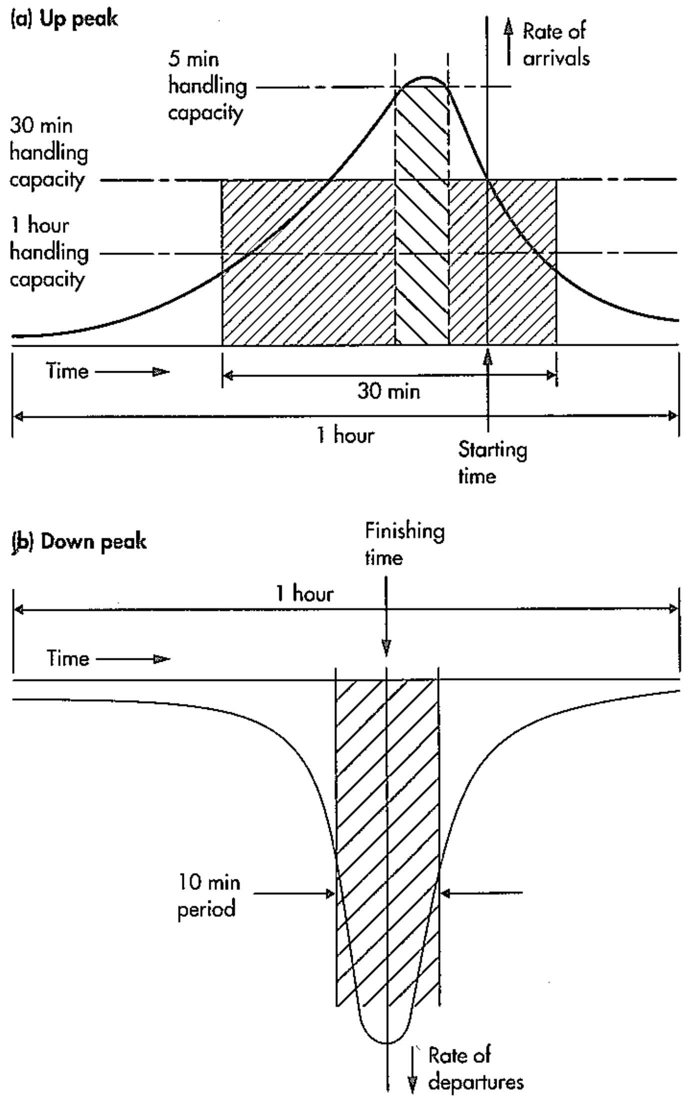

Figure 3.2 Detail of traffic profiles; (a) up-peak, (b) down-peak

3.3.3 Estimation of population

The size of the intended population should be obtained from the building owner or proposed occupier. If the population is not available or the building is a speculative one, then an estimation must be made. Most estimates start from a knowledge of the net lettable area, that is, the area which can be usefully occupied and which excludes circulation space (stairs, corridors, waiting areas), structural intrusions (steelwork, space heating, architectural features, etc.), toilet facilities, cleaners' areas, etc.

The number of occupants will vary according to the following:

- the purpose of the building (e.g. residential, commercial or institutional)
- the quality of the accommodation (i.e. the more prestigious the more space per occupant is required)
- the type of occupancy (in the case of office buildings whether it is single or multiple tenancy).

Table 3.1 gives guidance for a variety of buildings based on experience of the population to be accommodated.

Table 3.1 Estimation of population

Building type	Estimated population
Hotel	1.5–1.9 persons/room
Flats	1.5–1.9 persons/bedroom
Hospital	3.0 persons/bedspace†
School	0.8–1.2 m² net area/pupil
Office (multiple tenancy)	
— regular	10–12 m² net area/person
— prestige	15–25 m² net area/person
Office (single tenancy)	
— regular	8–10 m² net area/person
— prestige	12–20 m² net area/person

† excluding patient

- type of building occupancy (i.e. different business interests or single tenant)
- starting regime (i.e. unified or flexitime)
- location of bulk transit facilities such as buses and trains (distant alighting places will result in a spread of arrivals owing to different walking speeds).

The arrival rate is expressed as a percentage of the total population of the building. In many buildings it is unlikely that the total population is present on any particular day. For example a study by the Greater London Council(4) measured the attendance as 84%. In calculations, therefore, the total building population can be reduced by 15% to 20% to account for:

- persons on holiday
- persons away sick
- persons away on company business
- vacant posts
- persons who arrive before or after the peak hour of incoming traffic.

Table 3.2 gives guidance on probable peak arrival rates of the remaining occupants.

Table 3.2 Percentage arrival rates and up-peak intervals

Building type	Arrival rate (%)	Interval (s)
Hotel	10–15	30–50
Flats	5–7	40–90
Hospital	8–10	30–50
School	15–25	30–50
Office (multiple tenancy)		
— regular	11–15	25–30
— prestige	17	20–25
Office (single tenancy)		
— regular	15	25–30
— prestige	17–25	20–25

3.3.4 Quality of service

Actual average passenger waiting times, i.e. the time period between the instant of passenger arrival until the instant of arrival of the lift, would be the best indicator of the quality of service an installed lift system could provide; the shorter the average passenger waiting time the better the service. Unfortunately, average passenger waiting times cannot be easily measured owing to the difficulty of determining the exact arrival time for each passenger.

3.3.5 Estimation of arrival rate

It is necessary to determine the percentage of a building's population that will require transportation to the higher floors of a building during the morning up-peak of five minutes. This peak will vary due to effects such as:

What can be measured is the time for the lift system to respond to the hall call registered by the first arriving passenger. Some lift companies define the lift arrival time to be when the arrival signal is given (e.g. lantern or gong) or call registration cancellation. This will give optimistic results for performance as this signal can be as much as four seconds earlier than the actual lift arrival.

Some designers, therefore, use the interval of car arrivals at the main terminal as a representation of service quality. Note that 'interval' is part of the evaluation of handling capacity (see section 3.5) which represents the quantity of service of a lift system. However, in general terms, interval can be used to indicate the probable quality of service.

For office buildings the probable quality of service is related to the interval as follows:

- 20 s or less indicates an excellent system
- 25 s indicates a good system
- 30 s indicates a satisfactory system
- 40 s indicates a poor system
- 50 s or greater indicates an unsatisfactory system.

Table 3.2 gives guidance for values of suitable intervals for other types of buildings. These values supersede those given in *BS 5655: Part 6*(5) as the expectations of passengers, particularly in major city centre offices, have overtaken the recommendations given in *BS 5655*.

Caution must be exercised when using interval as a quality indicator as passenger waiting time depends on car occupancy i.e. number of passengers in the car (see section 3.6.1 and Figure 3.5). To a first approximation average passenger waiting time is 85% of the calculated interval at the standard assumed car loading of 80%. However, at 90% car loading the average passenger waiting time extends to 130% of the calculated interval.

Example 3.1

Determine the basic specification of the lift system for a speculative, non-prestige building having 10 floors (above the main terminal). Each floor has a net area of 1200 m^2.

Table 3.1 indicates 10 to 12 m^2/person should be allowed; assume 12 m^2, this gives 100 persons per floor. Therefore:

$$\text{total population} = 10 \times 100 = 1000$$

Assume 80% daily occupancy, giving a design population of 800. Table 3.2 indicates 11–15% arrival rate; assume 12.5%. Therefore:

$$\text{peak arrival} = 12.5 \times 800 = 100 \text{ persons}$$

Table 3.2 indicates an interval range of 25–30 s. Since this is a speculative building, use a 30 s interval to reduce capital costs.

Therefore the lift system should be sized to handle 100 persons with a 30 s interval.

3.4 Time components of a round trip

The up-peak traffic pattern, discussed in section 3.3.2, is the traffic pattern most easily analysed. It is characterised by passengers arriving at the main terminal for transportation to the upper floors. The lift system is usually arranged to bring all cars successively to the main terminal to load the passengers and take them to their destinations. Thus a multi-car lift system presents cars at the main terminal successively separated by a time interval. Figure 3.3 illustrates the 'up staircase' pattern of floor stops for a three car group.

To derive a formula for this activity consider Figure 3.4. This shows a typical single car trip around a building, the time of which is called the round trip time (RTT). This defines the round trip time as the average period of time

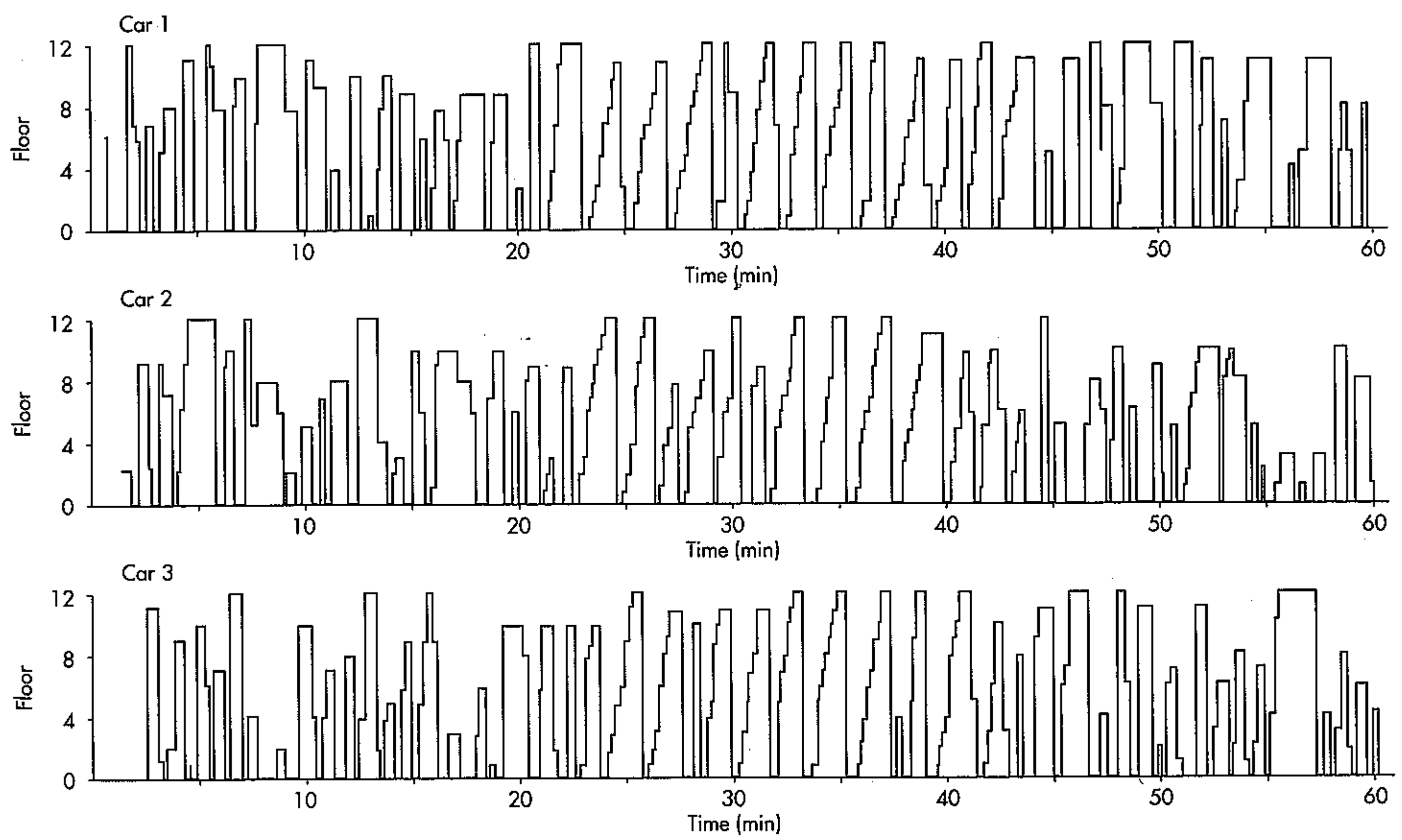

Figure 3.3 Car movements during up-peak traffic

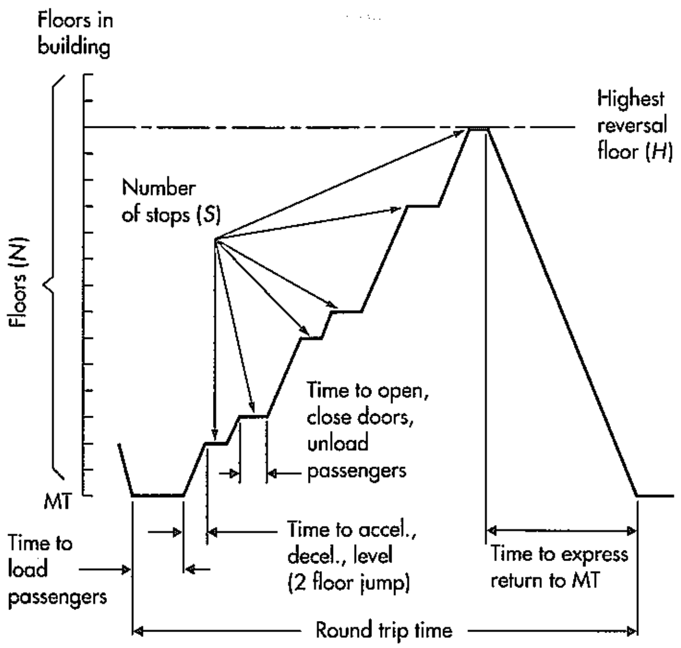

Figure 3.4 Components of round trip time

for a single car trip around a building, during the up-peak traffic condition, measured from the instant the car doors start to open at the main terminal to the instant the car doors start to reopen at the main terminal, when the car returns to the main terminal after its trip around the building.

The car trip is characterised by the average number of stops (S) and the average highest call reversal floor (H), which is the highest floor the lift visits during its trip before returning to the main floor. There are also a number of time components, which make up the total RTT:

- (*a*) time (t_l) to load P passengers into the car and the time (t_u) to unload P passengers out of the car
- (*b*) time to open (t_o) and close (t_c) the car doors at (S+1) floors
- (*c*) time to accelerate, run at rated speed, decelerate and level the car at (S+1) floors
- (*d*) time to travel past the remaining floors at rated speed to the highest call reversal floor (H)
- (*e*) time to make an express run from the highest floor (H) to the main terminal (MT).

The RTT (seconds) is given by:

$$\text{RTT} = (a) + (b) + (c) + (d) + (e) \tag{3.1}$$

$$\begin{aligned} &= P\,(t_l + t_u) + (S+1)\,(t_o + t_c) \\ &\quad + (S+1)\,t_{f(1)} + (H - S)\,t_v \\ &\quad + (H-1)\,t_v \end{aligned} \tag{3.2}$$

This simplifies to:

$$\text{RTT} = 2\,H\,t_v + (S{+}1)\,t_s + 2\,P\,t_p \tag{3.3}$$

where:

$$t_v = d_f / v \tag{3.4}$$

$$t_s = T - t_v \tag{3.5}$$

$$T = t_{f(1)} + t_c + t_o \tag{3.6}$$

$$t_p = (t_l + t_u) / 2 \tag{3.7}$$

where t_v is the time to transit two adjacent floors at rated speed (s), d_f is the average interfloor height (m), v is the rated speed (m/s), t_s is the time consumed when making a stop (s), T is the cycle time (s), $t_{f(1)}$ is the single (1) floor flight time (s), t_c is the door closing time (s), t_o is the door opening time (s), t_p is the average passenger transfer time entry or exit (s), t_l is the passenger loading time (s), t_u is the passenger unloading time (s).

The average number of passengers (P) assumed to load into a car during an up-peak traffic condition is taken as 80% of the rated capacity (see section 3.6.1) i.e.:

$$P = 0.8\ \text{CC} \tag{3.8}$$

where CC is the rated capacity of a car (persons).

Caution: note that some lift companies define cycle time to be the time from the instant the doors start to close until the instant the doors start to open even if the lift is still moving. Also, individual companies and consultants differ as to where to include the time for the doors to lock, motor field build-up delay, brake release delay, levelling time, etc. To avoid errors, careful note should be taken of the definitions used in this volume.

3.5 Up-peak interval, up-peak handling capacity and percentage population served

3.5.1 Determination of up-peak interval (UPPINT)

In an installation of one car the RTT is equal to the up-peak interval (UPPINT). In a system comprising several cars the up-peak interval (s) is given by:

$$\text{UPPINT} = \text{RTT} / L \tag{3.9}$$

where L is the number of cars.

3.5.2 Determination of up-peak handling capacity (UPPHC)

The up-peak handling capacity of a lift system is defined as the number of persons that can be transported from the main terminal to the upper floors of a building during the

five minutes (i.e. 300 seconds) of up-peak activity during which demand is heaviest. This is determined by finding the number of car trips in five minutes and multiplying it by the average number of passengers (P) carried in those five minutes.

The up-peak handling capacity (UPPHC) is given by the following equations.

For single car installations:

$$\text{UPPHC} = 300\,P / \text{UPPINT} \tag{3.10}$$

For multiple car installations:

$$\text{UPPHC} = 300\,P\,L / \text{RTT} \tag{3.11}$$

where L is the number of cars.

3.5.3 Determination of percentage population (%POP)

A value for %POP is obtained by dividing the UPPHC value by the effective population (U) for the building, see sections 3.3.3 and 3.3.4.

The percentage of a building's population (%POP) served during the peak five minutes is given by:

$$\%\text{POP} = \text{UPPHC} \times 100 / U \tag{3.12}$$

where U is the effective population of the building.

3.5.4 Calculation of up-peak lift performance

The design sequence for sizing a lift system for its up-peak performance is as follows:

- (*a*) calculate the RTT
- (*b*) select a suitable number of lifts
- (*c*) determine the UPPINT
- (*d*) calculate the UPPHC
- (*e*) calculate the %POP.

Step (*b*) is the most difficult as the number of lifts determines the UPPINT, which is often used to indicate the likely quality of the resulting lift system (see Table 3.2). The following is a rule of thumb for the general level of service provided by a single lift serving several floors:

- — one lift per 3 floors gives excellent service
- — one lift per 4 floors gives average service
- — one lift per 5 floors gives poor service.

However this general guide may be overridden by the need to achieve a specified interval or handling capacity. Note that all calculations provide average values.

3.6 Determination of parameters in RTT equation

3.6.1 Average number of passengers (*P*)

The average number of passengers carried per trip is an assumed value. Industry practice assumes a car loading of 80% of rated capacity. Many reasons are given for this assumption, such as:

- (*a*) Circulation problems within the car (e.g. the possibility that persons wishing to exit at the first stop are at the back of a crowded car) causing delays to the car's journey.
- (*b*) Obstruction of doors (e.g. collision of doors with passengers' bodies and items being carried), thus causing delays owing to door recycling.
- (*c*) Statistical effects: a facility which must respond to a demand will respond more quickly if it is only loaded to 80% of its capacity. (Similar effects are observed in other shared facilities, e.g. number of telephone circuits, number of bank tellers, number of users on an interactive computer system.)
- (*d*) Claustrophobic effects: i.e. passengers' dislike of crowded conditions.

Computer analysis[6] confirms that (*c*) is a plausible reason. The shape of the solid curve in Figure 3.5 indicates the wisdom of selecting an 80% car loading as a design criterion. Values less than 80% do not fully utilise the installation, and values above 80% quickly result in poor service times. Typically at a car load of 80% the passenger average waiting time is approximately 85% of the up-peak interval. Table 3.3 tabulates the graphical values.

Table 3.3 Tabulation of up-peak performance as shown in Figure 3.5

Car load	AWT/INT (%)
30	0.32
40	0.35
50	0.40
60	0.50
70	0.65
75	0.74
80	0.85
85	1.01
90	1.30
95	1.65

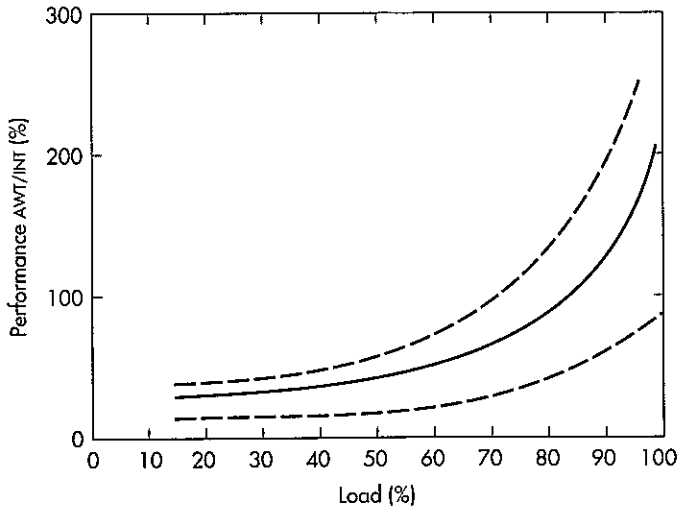

Figure 3.5 Up-peak performance: percentage load is the average car load as a percentage of car capacity, AWT is the average passenger waiting time and INT is the average interval at the specified car load for the lift system

Observers within the lift industry state that in practice cars are not observed to fill with passengers to the numbers permitted by the rating plate but a lower value between 60% to 70% of rated capacity, particularly in larger cars. This discrepancy is due to the assumed carrying capacity (rated capacity).

EN 81[7] sizes a lift car by a complicated formula of 0.1 m^2 plus an allowance of 0.2 m^2 per person up to 6 persons, then an allowance of 0.15 m^2 per person up to 20 persons, and then 0.12 m^2 per person thereafter. This implies that when riding in a 6-person car, each passenger can occupy 0.22 m^2, but when in a 33-person car the same passenger is only allocated 0.15 m^2 of space.

Another problem is that the whole of the platform area may not be available for passenger occupation, but may be reduced by architectural finishes (panels, handrails, mirrors, etc.). *ASME Code A17.1*[8] assumes a 5% reduction for this factor.

Allowing 0.2 m^2 per passenger, as recommended in section 2.2.2, the *EN 81* car sizes lead to the occupancies given in Table 3.4, confirming the industry observations of lower occupancies. This leads to the need to define the recommended carrying capacity as a lower value than that given in *EN 81* for the rated capacity. When making traffic calculations, it is recommended that the penultimate column of Table 3.4 be used to determine a value for P.

3.6.2 Average highest call reversal floor (H) and average number of stops (S)

Using statistical theory, Gaver and Powell[9] have determined H as:

$$H = N - \sum_{i=1}^{N-1} (i/N)^P \qquad (3.13)$$

where N is the number of floors above the main terminal, and P is the number of passengers carried.

Again using statistical theory, Basset Jones[2] has determined S as:

$$S = N(1-(1-1/N)^P) \qquad (3.14)$$

Table 3.5 gives values for H and S for a range of car sizes (following the ISO series) and for various numbers of floors above the main terminal. P is assumed to be 80% of rated capacity and values corresponding to the contract capacities are given in parentheses. Table 3.12 gives values for the actual numbers of passengers carried.

Knowing the contract capacity, Table 3.5 allows values of H and S to be read directly for the number of floors in the building zone under consideration; e.g. for 10 floors and 16-person cars, H = 9.7 and S = 7.4.

3.6.3 Single floor transit time (t_v)

This is the time that a car takes to transit two adjacent floors at rated speed and is defined by equation 3.4 as the average interfloor distance divided by the rated speed.

The interfloor distance (d_f) is the average interfloor distance normally determined as the total travel divided by the number of possible stopping floors above the MT. Domestic dwellings average about 3 m per floor and commercial buildings range from 3.3 m to 3.6 m or greater. Commercial buildings often introduce a mixed floor pitch for a number of reasons:

- Some floors have increased heights, such as lobby/main terminal floors, service floors, special floors (e.g. those containing a restaurant, lecture room, conference room, VIP suite etc.).
- Some floors are sometimes unavailable for alighting during periods of the day, such as first (and sometimes the second) floor above the MT, service floors, security floors.

It is recommended that a standard floor height be assumed, and the irregularities be dealt with separately, see section 3.8.6. Where a lift is serving a set of floors or zone in a building, which is not adjacent to the main terminal, an extra time to make the jump to or from the express zone must be added to equation 3.3 (i.e. $2\,H_e\,t_v$) where H_e is the distance of travel from the main terminal to the express zone terminal.

The value of the rated speed (v) is usually supplied by the lift maker, who will select it to meet various engineering requirements (i.e. gearing, drive controllers, product line considerations etc.) and traffic purposes. For instance, goods lifts are generally slower than passenger lifts. Speed, however, is not a dominant factor in equation 3.3, as illustrated by Example 3.2. It does become significant if the served floors are in an upper zone, where a higher speed will permit the unserved zone to be rapidly traversed.

If a value for v is not provided it must be chosen by the traffic designer.

Fire codes usually determine a minimum value by requiring that it shall be possible to travel to the highest floor in the building from the fire control entrance level in 60 s. Clearly this is not possible in very tall buildings and special arrangements must be made in these circumstances.

Section 4 of *BS 5655: Part 6*[5] recommends rated speeds in relation to total travel according to building usage. This can be translated into the time to travel at rated speed (without allowance for acceleration, deceleration or levelling) between the highest and lowest floors (the terminal floors), as shown in Table 3.6. This time is sometimes called the nominal travel time.

ISO 4190-6[10] recommends a maximum (theoretical) time of between 20 and 40 s to travel at the rated speed a distance equal to the total travel of the lift. The time is graded according to the likely interval at the main floor.

There is no theoretical upper limit to lift rated speed and it does not, for example, affect passenger comfort. However, it is limited by practical factors such as the maximum sheave diameter, rope bending radius, rope wear, safety (e.g. overtravel), etc.

Table 3.4 Determination of a value for P

Rated load† (kg)	Maximum area† (m^2)	Rated capacity† (persons)	Actual area‡ (m^2)	Actual maximum capacity‡ (persons)	P (persons)	P expressed as percentage of rated capacity (%)
450	1.30	6	1.24	6.2	4.9	82
630	1.66	8	1.58	7.9	6.3	79
800	2.00	10	1.90	9.5	7.6	76
1000	2.40	13	2.28	11.4	9.1	70
1250	2.90	16	2.76	13.8	11.0	69
1600	3.56	21	3.37	16.9	13.5	64
2000	4.20	26	3.99	20.0	16.0	61
2500	5.00	33	4.75	23.8	19.0	58

† Rated load, maximum area and rated capacity as given in *BS 5655*
‡ Actual area based on *BS 5655* maximum area less 5%; actual maximum population based on 0.2 m^2/person

Table 3.5 Values of H and S

Number of floors, N, above MT	H and S values for rated capacity†															
	6 (4.8)		8 (6.4)		10 (8.0)		13 (10.4)		16 (12.8)		21 (16.8)		26 (20.8)		33 (26.4)	
	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S
5	4.6	3.3	4.7	3.8	4.8	4.2	4.9	4.5	4.9	4.7	5.0	4.9	5.0	5.0	5.0	5.0
6	5.4	3.5	5.6	4.1	5.7	4.6	5.8	5.1	5.9	5.4	6.0	5.7	6.0	5.9	6.0	6.0
7	6.2	3.7	6.5	4.4	6.6	5.0	6.8	5.6	6.8	6.0	6.9	6.5	7.0	6.7	7.0	6.9
8	7.1	3.8	7.4	4.6	7.5	5.3	7.7	6.0	7.8	6.6	7.9	7.2	7.9	7.5	8.0	7.8
9	7.9	3.9	8.2	4.8	8.4	5.5	8.6	6.4	8.7	7.0	8.8	7.8	8.9	8.2	9.0	8.6
10	8.7	4.0	9.1	4.9	9.3	5.7	9.5	6.7	9.7	7.4	9.8	8.3	9.9	8.9	9.9	9.4
11	9.6	4.0	10.0	5.0	10.2	5.9	10.5	6.9	10.6	7.8	10.8	8.8	10.8	9.5	10.9	10.1
12	10.4	4.1	10.8	5.1	11.1	6.0	11.4	7.1	11.5	8.1	11.7	9.2	11.8	10.0	11.9	10.8
13	11.2	4.1	11.7	5.2	12.0	6.1	12.3	7.3	12.5	8.3	12.7	9.6	12.8	10.5	12.9	11.4
14	12.1	4.2	12.6	5.3	12.9	6.3	13.2	7.5	13.4	8.6	13.6	10.0	13.7	11.0	13.8	12.0
15	12.9	4.2	13.4	5.4	13.8	6.4	14.1	7.7	14.3	8.8	14.6	10.3	14.7	11.4	14.8	12.6
16	13.7	4.3	14.3	5.4	14.7	6.5	15.0	7.8	15.3	9.0	15.5	10.6	15.7	11.8	15.8	13.1
17	14.5	4.3	15.3	5.5	15.6	6.5	16.0	8.0	16.2	9.2	16.5	10.9	16.6	12.2	16.8	13.6
18	15.4	4.3	16.0	5.5	16.6	6.6	16.9	8.1	17.1	9.3	17.4	11.1	17.6	12.5	17.7	14.0
19	16.2	4.3	16.9	5.6	17.4	6.7	17.8	8.2	18.1	9.5	18.4	11.3	18.5	12.8	18.7	14.4
20	17.0	4.4	17.8	5.6	18.2	6.7	18.7	8.3	19.0	9.6	19.3	11.6	19.5	13.1	19.7	14.8
21	17.9	4.4	18.6	5.6	19.1	6.8	19.6	8.4	19.9	9.8	20.3	11.7	20.5	13.4	20.6	15.2
22	18.7	4.4	19.5	5.7	20.0	6.8	20.5	8.4	20.9	9.9	21.2	11.9	21.4	13.6	21.6	15.6
23	19.5	4.4	20.4	5.7	20.9	6.9	21.4	8.5	21.8	10.0	22.1	12.1	22.4	13.9	22.6	15.9
24	20.3	4.4	21.2	5.7	21.8	6.9	22.4	8.6	22.7	10.1	23.1	12.3	23.3	14.1	23.5	16.2

† 80% capacity shown in parentheses

Table 3.6 Total time required to travel between terminal floors in different building types

Building type	Transit time (s)
Offices	
— large	17–20
— small	20
Hotels	
— large	17–20
— small	20
Hospitals	24
Nursing and residential homes	24
Residential buildings	20–30
Factories and warehouses	24–40
Shops	24–40

Table 3.7 provides guidance on the selection of the speed of a lift based on the premise that the total time to travel the distance between terminal floors at rated speed should take between 20 and 30 s. In the table the single floor flight times assume a 3.3 m interfloor distance and are slightly larger than theoretically derived values to allow for brake lift delays and other start-up delays.

Table 3.7 Typical lift dynamics

Lift travel (m)	Rated speed (m/s)	Acceleration (m/s^2)	Single floor flight time (s)
<20	<1.00	0.4	10.0
20	1.00	0.4–0.7	7.0
32	1.60	0.7–0.8	6.0
50	2.50	0.8–0.9	5.5
63	3.15	1.0	5.0
100	5.00	1.2–1.5	4.5
120	6.00	1.5	4.3
>120	>6.00	1.5	4.3

3.6.4 Time consumed when stopping (t_s)

Combining equations 3.5 and 3.6 gives the following equation:

$$t_s = t_{f(1)} + t_c + t_o - t_v \qquad (3.15)$$

The time to transit two adjacent floors at rated speed (t_v) is dealt with in section 3.6.3.

The floor cycle time (T) has the most effect on RTT (see equation 3.3). This is the time taken between the instant when a stationary lift starts to close its doors and the instant when its the doors are 90% open at the next adjacent floor.

The components of the floor cycle time must be carefully selected to achieve the correct handling capacity for the lift installation. The lift maker should be contracted at the tender stage to provide them at the specified values and the maintenance contractor should be required to keep them at the contract values throughout the life of the installation. Failure to do so will invalidate any traffic design.

The single floor flight time $t_{f(1)}$ is the time taken from the instant the car doors close to the instant the car is level with the next adjacent floor. It is dependent on the rated speed, the acceleration and the jerk. Jerk, sometimes called 'shock' is the rate of change of acceleration, i.e. m/s^3. The relationships between distance travelled, velocity, acceleration and jerk are complex and are given in detail in section 11.4.3. Thus flight times can be obtained for any distance or number of floors travelled.

Fortunately for designers of lift drives there are limits on the maximum values of both acceleration and jerk. These constraints are imposed by human physiology. Passengers are uncomfortable when subjected to acceleration greater than about one sixth of the acceleration due to gravity (i.e. about 1.5 m/s^2). Similarly, the maximum value of jerk is about 2.2 m/s^3.

Table 3.7 indicates the likely range of acceleration values and single floor flight times. The single floor flight times are slightly larger than a theoretical calculation would give to allow for start-up delays.

The door closing time (t_c) is the time taken from the instant the car doors start to close to the time they are locked up. This time is dependent on door width, type and weight.

There are several standard widths. Narrow doors of 0.8 m width are fitted to cars with a rated capacity of up to 12 persons; wider doors are fitted for lifts with greater rated capacity. Doors of 1.3 m width are fitted on goods lifts and hospital lifts.

There are two basic door types: side-opening and centre-opening (see section 6.8). Side-opening doors have to open the whole width of the doorway, which takes more time. Centre-opening doors open and close more quickly and the symmetrical reaction against the car frame will reduce car sway.

The weight of the door is determined by many factors such as fire resistance, height, width, configuration etc. A moving door gathers considerable kinetic energy. To protect passengers from injury, European Standard *EN 81*[7] requires the maximum energy to be limited to 10 J, provided the safety edge is operative. If the safety edge is inoperative then the energy value must not exceed 4 J.

The maximum values of energy acquisition limit the maximum door speed when closing. Typically a 150 kg door has a maximum speed of 0.23 m/s and a 500 kg door has a maximum speed of 0.13 m/s.

The door opening time (t_o) is the time from the instant that the car is level at the next adjacent landing to the instant that the doors are 90% open (i.e. when the doors are open wide enough for passengers to pass through). Door opening time is not subject to energy constraints and, provided that the trapping hazard between door panel and door architrave is negligible, it can operate at any speed. However, as the same door operator will be used for both directions of movement, opening times will not be significantly improved.

An improvement in opening times can be achieved by overlapping the levelling operation with the first part of the opening of the doors (called advanced door opening). This is possible within the door zone (0.2 m of floor level, see *EN 81*[7]) and provided the doors are 0.6 m open, there is no tripping hazard.

Table 3.8 gives representative values for two door types, two door sizes and with and without advanced opening, which may be used where specific values are not available. A fuller range of door times for a wider selection of door operators is given in Table 6.1.

Table 3.8 Typical door closing and opening times

Door type†	Opening and closing times (s) for stated door width (m)					
	Opening (advanced)		Opening (normal)		Closing	
	0.8	1.1	0.8	1.1	0.8	1.1
Side	1.0	1.5	2.5	3.0	3.0	4.0
Centre	0.5	0.8	2.0	2.5	2.0	3.0

† see Table 6.1 for fuller range of door times

3.6.5 Passenger transfer time (t_p)

The passenger transfer time is the time a single passenger takes to enter or leave a car. This parameter is the most vague of all the components of equation 3.3, principally because it is dependent on human behaviour. The passenger transfer time can vary considerably and is affected by the shape of the car, the size and type of car entrance, the building type (e.g. commercial, institutional, residential etc.) and the characteristics of the passengers (e.g. age, agility, purpose etc.).

Jones[11] and Phillips[12] report studies on passenger behaviour from which general rules can be deduced. If the car door width is 1.0 m or less it may be assumed that passengers enter or exit in single file. For door widths of 1.0 m and above it may be assumed that the first six passengers enter or exit in single file and the remainder in double file. The average passenger transfer time (entry or exit) may be taken as 1.2 s. For situations where passengers are elderly or have no reason to rush the transfer times should be increased to about 2 s. *ISO 4190-6*[10] considers a passenger transfer time of 1.75 s suitable for residential buildings.

Example 3.2

Two tenders have been received for the provision of 5 lifts of 10-person capacity in a 15-storey office block having an interfloor height of 3.3 m. Assume a passenger transfer time of 1.2 s. Compare the two tenders.

The tender information is given in Table 3.9. Table 3.10 gives data deduced from the above tables and equations.

Table 3.9 Example 3.2: tender information

Parameter	Tender A	Tender B
Rated speed (m/s)	1.6	2.5
Door opening time (s)	1.0	3.0
Door closing time (s)	3.0	3.5
Single floor flight time (s)	6.0	5.5

Table 3.10 Example 3.2: deduced data

Parameter	Tender A	Tender B	Deduced from
Average number of passengers (P)	8.0	8.0	(CC = 10)
Average highest floor (H)	13.8	13.8	(Table 3.5)
Average number of stops (S)	6.4	6.4	(Table 3.5)
Transit time (t_v)	2.06	1.32	(equation 3.4)
Stopping time (t_s)	7.94	10.68	(equations 3.5, 3.6)
Passenger transfer time (t_p)	1.2	1.2	(design brief)
Cycle time (T)	10.0	12.0	(equation 3.6)

Calculation of RTT for Tender A is as follows:

$$\text{RTT} = (2 \times 13.8 \times 2.06) + 7.4\,(6.0 + 1.0 + 3.0 - 2.06) + (2 \times 8 \times 1.2)$$
$$= 56.9 + 58.8 + 19.2$$
$$= 134.9 \text{ s}$$

Calculation of RTT for Tender B is as follows:

$$\text{RTT} = (2 \times 13.8 \times 1.32) + 7.4\,(5.5 + 3.0 + 3.5 - 1.32) + (2 \times 8 \times 1.2)$$
$$= 36.4 + 79.0 + 19.2$$
$$= 134.6 \text{ s}$$

Note that both tenders give a similar RTT value but obtained in different ways. The slower system would appear to offer centre opening doors and the faster appears to offer side opening doors. Note how the values of the first and central terms change in the round trip equation.

Example 3.3

Design a lift system to meet the requirements of Example 3.1, i.e. to handle 100 persons with a 30 s interval (see section 3.3.5). Assume an interfloor distance of 3.3 m.

Estimate car size to handle 100 persons in 5 minutes with an UPPINT of 30 s:

- number of trips in 5 minute period: 300/30 = 10
- number of persons per trip: 100/10 = 10
- required car size: 10/0.8 = 12.5 persons

A 13-person car is the nearest standard size. Then, from Table 3.5; $H = 9.5$, $S = 6.7$, $P = 10.4$.

Decide on the lift system:

- total travel is 33 m; use a rated speed of 1.6 m/s
- transit time will be: 3.3/1.6 = 2.1 s
- Table 3.7 indicates a suitable single floor flight time of 6.0 s
- select centre opening doors
- from Table 3.8: $t_o = 0.8$ s; $t_c = 3.0$ s
- stopping time is: 6.0 + 0.8 + 3.0 − 2.1 = 7.7 s

Assume passenger transfer time is 1.2 s.

Then:

$$\text{RTT} = (2 \times 9.5 \times 2.1) + (7.7 \times 7.7) + (2 \times 10.4 \times 1.2)$$

$$= 39.9 + 59.3 + 25.0$$

$$= 124.2 \text{ s}$$

To achieve an interval of about 30 s, 4 cars will be needed, therefore:

UPPINT = 31.1 s

UPPHC = 100.3 person/5 min

The required system is 4 cars of 13-person rated capacity.

Notes on Examples 3.2 and 3.3

Examination of the three terms in the equation for RTT shows that the central term is the most influential. Thus saving one second on the cycle time (T) increases the handling capacity by about 5%. For a 3.3 m interfloor height the following values of T indicate the probable performance of an installed lift system:

- $T < 8.0$ s is probably impossible
- $8.0 \text{ s} < T < 9.0$ s indicates an excellent system
- $9.0 \text{ s} < T < 10.0$ s indicates a good system
- $10.0 \text{ s} < T < 11.0$ s indicates an average system
- $11.0 \text{ s} < T < 12.0$ s indicates a poor system
- $T > 12.0$ s indicates that system replacement should be considered.

The first term is dependent on the rated speed (v) but t_s increases as t_v decreases. The last term is completely dependent on passenger behaviour and is not under the designer's control.

3.7 Determination of RTT using tables and graphs

3.7.1 General

There are a finite number of suitable combinations of rated speeds and rated capacities for particular numbers of floors. Attempts have been made to provide selection tables and graphs to aid the designer, such as Tables 3 and 4 in *BS 5655: Part 6*[5]. Unfortunately some of the information on which the tables are based is not given. The tables provide data for some of the variables of the RTT calculation, namely d_f, v, CC and N. However, data for H, S, P, $t_{f(1)}$, t_o, t_c, and t_p are omitted. Using computer analysis, Barney[13] derived the missing values, as follows:

- P is 80% rated capacity
- S is according to Table 3.5
- H is equal to N
- t_p is 1.0 s
- T is 9.5 s at speeds of 1.0 m/s, 8.0 or 8.75 s at 1.6 m/s, 8.25 s at 2.5 m/s and 8.60 s at 3.5 m/s.

The *BS 5655* tables should be used only if the designer agrees that the data set given above fits the system under design. Note that the value used for H is a simplification and also that T includes t_o, t_c and $t_{f(1)}$.

ISO 4190-6[10] attempts to provide graphs for the selection of lifts for residential buildings. The graphs are drawn for specified lift configurations and all required data are given. However, lift selection depends on the requirement for the total population (x axis) and the floors served (y axis) to intersect in a broad sector of the graph. This results in intervals not consistent with the particular graph selected and overprovision of handling capacity[13].

In addition the proposed lift configurations are not suitable for the UK and *ISO 4190-6* is therefore not adopted in the UK. This method of selection is too crude to yield accurate results and is not recommended.

3.7.2 'Ready reckoner' tables for RTT

Although the solution of the RTT equation is simple and quick to apply it is useful to have access to a set of 'ready reckoner' tables for buildings with from 3 to 24 floors per zone served by lifts of rated capacity 6 to 33 persons (see Table 3.11).

The variables, their possible ranges and pertinent comments are as follows:

- Number of floors about MT served (N): building zones from 3 to 24 floors above the main terminal may be selected.
- Rated speed (v): two standard ISO speeds are given for each value of N. (The rated speed is generally selected to permit a journey between terminal floors in a building zone to be accomplished in 20 to 30 s.)
- Rated capacity (CC): eight values are given from 6 to 33 persons (450 to 2500 kg).
- Cycle time (T): a single value of 10 s is used. To accommodate cycle times other than 10 s, a value of $\pm \Delta T$ is quoted for a ± 10% variation (i.e. ± 1.0 s).
- Interfloor distance (d_f): a standard value of 3.3 m is used. To accommodate distances other than 3.3 m, a value of $\pm \delta t$ is quoted for a ± 10% variation (i.e. ± 0.33 m). This variation (δt) also accommodates a ± 9% variation in rated speed.
- Passenger transfer time (t_p): a standard value of 1.0 s is used. To accommodate different transfer times the variation in RTT (δt_p) corresponding to a change of ± 0.2 s in t_p is quoted at the foot of each RTT column in the table.

Example 3.4

Evaluate Tender B (Example 3.2) using Table 3.11. Tender data are as follows: $N = 15$, CC = 10, $v = 2.5$, $T = 12$, $d_f = 3.3$, $t_p = 1.2$.

From Table 3.11, find $N = 15$ and $v = 2.5$ in the left hand column. Follow across the page until the column for CC = 10 is reached. Hence RTT is 116.3 s.

As T is 12 s (i.e. 20% greater than the base cycle time of 10 s), add twice the value given in the ΔT column. Therefore, correction $\Delta T = 2 \times 7.4 = +14.8$ s.

As t_p is 1.2 s (i.e. 20% greater than the base passenger transfer time of 1.0 s), add the value at the foot of the column. Therefore, correction for t_p is +3.2 s.

Thus the final value for RTT is:

$$(116.3 + 14.8 + 3.2) = 134.3 \text{ s}$$

This is a similar value to that obtained in Example 3.2.

Example 3.5

Use Table 3.11 to evaluate Example 3.3. Data are: $N = 10$, CC = 13, $v = 1.6$, $T = 9.8$, $d_f = 3.3$, $t_p = 1.2$.

From Table 3.11:

RTT = 120.9

As T is 9.8, subtract 0.2 × 7.7 = 1.5

As t_p is 1.2, add 4.2

Hence, final value for RTT is (120.9 − 1.5 + 4.2) = 123.6 s.

The values obtained from Table 3.11 differ slightly from the results obtained in Examples 3.2 and 3.3. However, they are more accurate because they were calculated by computer and are subject to less rounding error.

3.8 Limitations of RTT equation

3.8.1 General

A number of assumptions were made in the derivation of equation 3.3 which place limits on the validity of the method. It is important for the designer to be aware of these limitations, especially when using tables or computer calculation techniques.

3.8.2 Average highest reversal floor (H)

A common practice has been to assume that the highest call reversal floor is equal to the number of served floors (N) for building zones up to 16 floors and (N − 1) for building zones greater than 16 floors. This assumption leads to large errors in some circumstances, as illustrated in Figure 3.6. It is recommended that H be calculated using equation 3.13 to avoid this potential error.

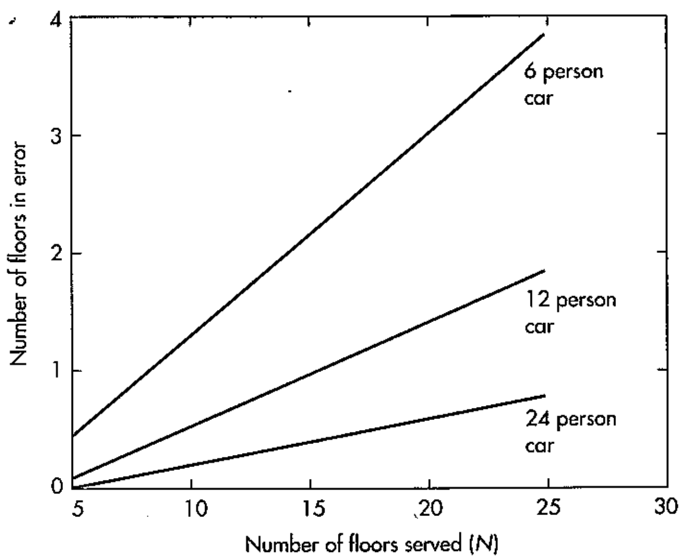

Figure 3.6 Error in H assuming it to be the highest floor

Table 3.11 Ready reckoner for determination of RTT, ΔT and δt

(*a*) 6- to 13-person cars, 3 to 24 floors above main terminal

Number of served floors, N, above MT	Rated speed, v (m/s)	Rated capacity (person) and rated load (kg): 6 person (450 kg) RTT (s)	6 person ΔT (s)	6 person δt (s)	8 person (650 kg) RTT (s)	8 person ΔT (s)	8 person δt (s)	10 person (800 kg) RTT (s)	10 person ΔT (s)	10 person δt (s)	13 person (1000 kg) RTT (s)	13 person ΔT (s)	13 person δt (s)
3	0.63	56.5	3.6	1.1	61.4	3.8	1.1	65.5	3.9	1.1	70.9	4.0	1.1
3	1.00	52.4	3.6	0.7	57.4	3.8	0.7	61.6	3.9	0.7	67.0	4.0	0.7
4	0.63	67.5	4.0	1.8	73.7	4.4	1.7	78.7	4.6	1.7	85.0	4.8	1.6
4	1.00	60.9	4.0	1.1	67.3	4.4	1.1	72.5	4.6	1.1	79.0	4.8	1.0
5	1.00	68.4	4.3	1.6	76.1	4.8	1.5	82.4	5.2	1.5	90.0	5.5	1.4
5	1.60	62.4	4.3	1.0	70.4	4.8	1.0	76.8	5.2	0.9	84.7	5.5	0.9
6	1.00	75.4	4.5	2.1	84.2	5.1	2.0	91.3	5.6	1.9	100.2	6.1	1.8
6	1.60	67.6	4.5	1.3	76.6	5.1	1.3	84.1	5.6	1.2	93.3	6.1	1.1
7	1.00	82.0	4.7	2.6	91.7	5.4	2.6	99.7	6.0	2.4	109.6	6.6	2.3
7	1.60	72.3	4.7	1.6	82.3	5.4	1.6	90.7	6.0	1.5	101.0	6.6	1.4
8	1.60	76.8	4.8	1.9	87.6	5.6	1.9	96.7	6.3	1.8	108.1	7.0	1.7
8	2.50	69.8	4.8	1.2	80.8	5.6	1.2	90.1	6.3	1.2	101.9	7.0	1.1
9	1.60	81.0	4.9	2.3	92.5	5.8	2.2	102.3	6.5	2.1	114.7	7.4	2.0
9	2.50	72.9	4.9	1.4	84.6	5.8	1.4	94.6	6.5	1.4	107.4	7.4	1.3
10	1.60	85.1	5.0	2.6	97.2	5.9	2.5	107.6	6.7	2.5	120.9	7.7	2.4
10	2.50	75.8	5.0	1.7	88.1	5.9	1.6	98.7	6.7	1.6	112.4	7.7	1.5
11	2.50	78.6	5.0	1.9	91.4	6.0	1.8	102.6	6.9	1.8	117.1	7.9	1.7
11	3.15	74.8	5.0	1.5	87.6	6.0	1.5	98.9	6.9	1.4	113.6	7.9	1.4
12	2.50	81.3	5.1	2.1	94.6	6.1	2.1	106.2	7.0	2.0	121.5	8.1	1.9
12	3.15	77.0	5.1	1.6	90.3	6.1	1.6	102.1	7.0	1.6	117.6	8.1	1.5
13	2.50	83.9	5.1	2.3	97.6	6.2	2.3	109.7	7.1	2.2	125.7	8.3	2.1
13	3.15	79.2	5.1	1.8	92.9	6.2	1.8	105.1	7.1	1.8	121.3	8.3	1.7
14	2.50	86.5	5.2	2.5	100.6	6.3	2.5	113.1	7.3	2.4	129.7	8.5	2.4
14	3.15	81.3	5.2	2.0	95.4	6.3	2.0	108.0	7.3	1.9	124.8	8.5	1.9
15	2.50	89.0	5.2	2.7	103.4	6.4	2.7	116.3	7.4	2.7	133.4	8.7	2.6
15	3.15	83.4	5.2	2.2	97.8	6.4	2.1	110.8	7.4	2.1	128.1	8.7	2.1
16	3.15	85.4	5.3	2.3	100.2	6.4	2.3	113.5	7.5	2.3	131.3	8.8	2.2
16	4.00	80.5	5.3	1.8	95.3	6.4	1.8	108.6	7.5	1.8	126.6	8.8	1.8
17	3.15	87.5	5.3	2.5	102.5	6.5	2.5	116.1	7.5	2.5	134.4	9.0	2.4
17	4.00	82.2	5.3	2.0	97.2	6.5	2.0	110.8	7.5	1.9	129.3	9.0	1.9
18	3.15	89.4	5.3	2.7	104.7	6.5	2.7	118.6	7.6	2.7	137.3	9.1	2.6
18	4.00	83.8	5.3	2.1	99.0	6.5	2.1	112.9	7.6	2.1	131.8	9.1	2.0
19	3.15	91.4	5.3	2.8	106.9	6.6	2.9	121.0	7.7	2.8	140.2	9.2	2.8
19	4.00	85.4	5.3	2.2	100.9	6.6	2.2	115.0	7.7	2.2	134.3	9.2	2.2
20	3.15	93.3	5.4	3.0	109.1	6.6	3.0	123.4	7.7	3.0	143.0	9.3	2.9
20	4.00	86.9	5.4	2.4	102.6	6.6	2.4	117.0	7.7	2.4	136.7	9.3	2.3
21	4.00	88.5	5.4	2.5	104.4	6.6	2.5	119.0	7.8	2.5	139.0	9.4	2.5
21	5.00	83.5	5.4	2.0	99.3	6.6	2.0	114.0	7.8	2.0	134.1	9.4	2.0
22	4.00	90.0	5.4	2.6	106.1	6.7	2.7	120.9	7.8	2.7	141.3	9.4	2.6
22	5.00	84.7	5.4	2.1	100.8	6.7	2.1	115.6	7.8	2.1	136.1	9.4	2.1
23	4.00	91.5	5.4	2.8	107.8	6.7	2.8	122.8	7.9	2.8	143.5	9.5	2.8
23	5.00	86.0	5.4	2.2	102.2	6.7	2.2	117.2	7.9	2.2	138.0	9.5	2.2
24	4.00	93.0	5.4	2.9	109.5	6.2	2.9	124.7	7.9	2.9	145.6	9.6	2.9
24	5.00	87.2	5.4	2.3	103.6	6.7	2.4	118.8	7.9	2.4	139.8	9.6	2.3
δt_p (s):		1.9			2.6			3.2			4.2		

Table 3.11 — *continued*

(*b*) 16- to 33-person cars, 3 to 24 floors above main terminal

Number of served floors, N, above MT	Rated speed, v (m/s)	Rated capacity (person) and rated load (kg): 16 person (1250 kg) RTT (s)	16 person ΔT (s)	16 person δt (s)	21 person (1600 kg) RTT (s)	21 person ΔT (s)	21 person δt (s)	26 person (2000 kg) RTT (s)	26 person ΔT (s)	26 person δt (s)	33 person (2500 kg) RTT (s)	33 person ΔT (s)	33 person δt (s)
3	0.63	75.9	4.0	1.1	84.0	4.0	1.0	92.1	4.0	1.0	103.3	4.0	1.0
3	1.00	72.1	4.0	0.7	80.2	4.0	0.7	88.2	4.0	0.7	99.4	4.0	0.7
4	0.63	90.6	4.9	1.6	99.1	5.0	1.6	107.2	5.0	1.6	118.5	5.0	1.6
4	1.00	84.7	4.9	1.0	93.2	5.0	1.0	101.4	5.0	1.0	112.7	5.0	1.0
5	1.00	96.5	5.7	1.4	105.9	5.9	1.3	114.4	6.0	1.3	125.9	6.0	1.3
5	1.60	91.3	5.7	0.9	100.8	5.9	0.8	109.4	6.0	0.8	120.9	6.0	1.3
6	1.00	107.5	6.4	1.8	117.9	6.7	1.7	127.0	6.9	1.7	138.9	7.0	1.7
6	1.60	100.9	6.4	1.1	111.5	6.7	1.1	120.7	6.9	1.0	132.7	7.0	1.0
7	1.00	117.9	7.0	2.2	129.4	7.5	2.1	139.2	7.7	2.0	151.7	7.9	2.0
7	1.60	109.6	7.0	1.4	121.5	7.5	1.3	131.6	7.7	1.3	144.2	7.9	1.3
8	1.60	117.7	7.6	1.7	130.8	8.2	1.6	141.8	8.5	1.5	155.2	8.8	1.5
8	2.50	111.7	7.6	1.1	125.2	8.2	1.0	136.4	8.5	1.0	149.9	8.8	0.9
9	1.60	125.2	8.0	2.0	139.6	8.8	1.8	151.6	9.2	1.8	165.9	9.6	1.7
9	2.50	118.2	8.0	1.2	133.0	8.8	1.2	145.2	9.2	1.1	159.8	9.6	1.1
10	1.60	132.2	8.4	2.3	147.8	9.3	2.1	160.8	9.9	2.0	176.2	10.4	2.0
10	2.50	124.1	8.4	1.4	140.2	9.3	1.4	153.5	9.9	1.3	169.1	10.4	1.3
11	2.50	129.6	8.8	1.6	146.9	9.8	1.5	161.2	10.5	1.5	178.1	11.1	1.4
11	3.15	126.2	8.8	1.3	143.7	9.8	1.2	158.2	10.5	1.2	175.1	11.1	1.1
12	2.50	134.7	9.1	1.9	153.2	10.2	1.7	168.6	11.0	1.7	186.6	11.8	1.6
12	3.15	130.9	9.1	1.5	149.6	10.2	1.4	165.1	11.0	1.3	183.3	11.8	1.3
13	2.50	139.6	9.3	2.1	159.1	10.6	1.9	175.5	11.5	1.8	194.6	12.4	1.8
13	3.15	135.3	9.3	1.6	155.1	10.6	1.5	171.7	11.5	1.5	191.0	12.4	1.4
14	2.50	144.1	9.6	2.3	164.8	11.0	2.1	182.1	12.0	2.0	202.4	13.0	1.9
14	3.15	139.4	9.6	1.8	160.3	11.0	1.7	177.8	12.0	1.6	198.4	13.0	1.5
15	2.50	148.5	9.8	2.5	170.1	11.3	2.4	188.3	12.4	2.2	209.7	13.6	2.1
15	3.15	143.4	9.8	2.0	165.2	11.3	1.9	183.7	12.4	1.8	205.3	13.6	1.7
16	3.15	147.1	10.0	2.2	169.9	11.6	2.0	189.2	12.8	1.9	212.0	14.1	1.8
16	4.00	142.5	10.0	1.7	165.5	11.6	1.6	185.1	12.8	1.5	208.1	14.1	1.4
17	3.15	150.7	10.2	2.3	174.3	11.9	2.2	194.4	13.2	2.1	218.3	14.6	2.0
17	4.00	145.7	10.2	1.8	169.6	11.9	1.7	190.0	13.2	1.7	214.1	14.6	1.6
18	3.15	154.1	10.3	2.5	178.5	12.1	2.4	199.5	13.5	2.3	224.4	15.0	2.1
18	4.00	148.7	10.3	2.0	173.4	12.1	1.9	194.6	13.5	1.8	219.9	15.0	1.7
19	3.15	157.4	10.5	2.7	182.5	12.3	2.6	204.2	13.8	2.4	230.2	15.4	2.3
19	4.00	141.7	10.5	2.1	177.1	12.3	2.0	199.1	13.8	1.9	225.3	15.4	1.8
20	3.15	160.5	10.6	2.9	186.4	12.6	2.7	208.8	14.1	2.6	235.8	15.8	2.5
20	4.00	154.5	10.6	2.3	180.6	12.6	2.2	203.3	14.1	2.1	230.5	15.8	1.9
21	4.00	157.1	10.8	2.4	184.0	12.7	2.3	207.4	14.4	2.2	235.6	16.2	2.1
21	5.00	152.3	10.8	1.9	179.4	12.7	1.8	203.0	14.4	1.8	231.4	16.2	1.7
22	4.00	159.8	10.9	2.5	187.2	12.9	2.4	211.3	14.6	2.3	240.4	16.6	2.2
22	5.00	154.7	10.9	2.0	182.4	12.9	1.9	206.6	14.6	1.9	236.0	16.6	1.8
23	4.00	162.3	11.0	2.7	190.3	13.1	2.6	215.0	14.9	2.5	245.0	16.9	2.3
23	5.00	156.9	11.0	2.2	185.2	13.1	2.1	210.1	14.9	2.0	240.3	16.9	1.9
24	4.00	164.7	11.1	2.8	193.4	13.3	2.7	218.6	15.1	2.6	249.4	17.2	2.5
24	5.00	159.1	11.1	2.3	187.9	13.3	2.2	213.4	15.1	2.1	244.5	17.2	2.0
δt_p (s):		5.1			6.7			8.3			10.6		

3.8.3 Arrival time of passengers

The equations for H and S (equations 3.13 and 3.14) are based on the assumption that passengers normally arrive at a lift system for transportation, according to a rectangular probability distribution function (PDF). This means that the periods of time between successive passenger arrivals are assumed to be equal for a constant arrival rate and to change linearly for varying arrival rates.

It is more likely that the human arrival processes will be according to a Poisson PDF, in which the passenger inter-arrival periods are related non-linearly, even for a constant arrival rate.

Barney and Dos Santos[6] have shown that if the formulae for H and S are derived using the Poisson PDF then the resulting values are always smaller than those for a rectangular PDF. They show also that other PDFs (e.g. the Erlangian) produce results between the rectangular and the Poisson. Thus the use of equations based on the rectangular PDF produce slightly oversized designs, when compared with those obtained using equations derived from the Poisson PDF.

Table 3.12 enables values of H and S to be easily found by simple interpolation. It is then possible to deal with any specific arrival rate.

3.8.4 Population of floors

Generally the floors of a building are not equally populated. Using the rectangular PDF, the following equations for H and S can be derived:

$$H = N - \sum_{j=1}^{N-1}\left(\sum_{i=1}^{j}(U_i/U)\right)^P \qquad (3.16)$$

$$S = N - \sum_{i=1}^{N}\left(1-(U_i/U)\right)^P \qquad (3.17)$$

where U_i is the population of floor i.

It is not possible tabulate values for H and S to cover the wide range of eventualities for unequal populations.

Figure 3.7 shows three possible population distributions for a 10-storey building: (*a*) equal population, (*b*) unequal population, with most of the population in the upper parts of the building (unlikely), (*c*) unequal population, with most of the population in the lower parts of the building (likely).

The values of H and S determined using equations 3.16 and 3.17 are indicated on Figure 3.7. In cases (*b*) and (*c*) the value of S decreased by the same amount, in this instance by over 10%. The value for H is increased for case (*b*) by about 5% and decreased for case (*c*) by about 20%, as would be expected with such a population distribution.

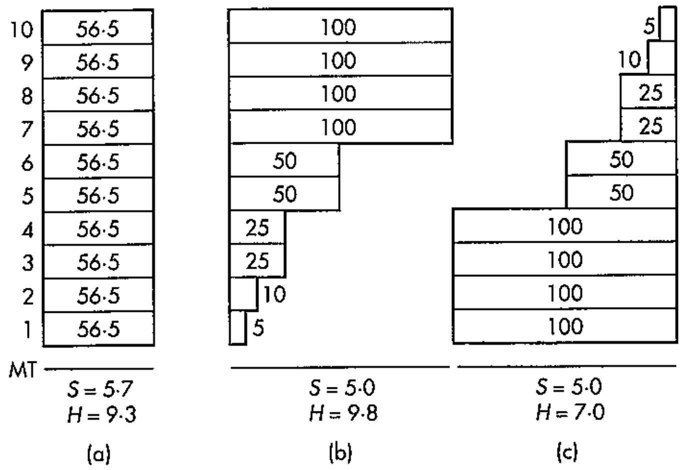

Figure 3.7 Effect of unequal floor populations on H and S values; (a) equal population, (b) unequal population, most of population in upper parts of building, (c) unequal population, most of population in lower parts of building

Therefore the effect of an unequal population is generally favourable to the sizing of a lift system.

3.8.5 Car loading

The equation for RTT assumes that cars will load, on average, to 80% of their rated capacity. The value obtained for UPPHC also makes the same assumption. This is only correct if the arrival rate (A_r) exactly equals UPPHC. If too few or too many passengers arrive to load the cars the car load will not be 80% and the values for S, H, RTT and interval (INT) will alter. It is possible to calculate the interval and car load for a defined passenger arrival rate.

It is common practice to select the desired value for a car interval (INT). If the passenger arrival rate is A_r persons per second then the number of passengers (P) per car is given by:

$$P = A_r \times \text{INT} \qquad (3.18)$$

Given values of t_v, t_s and t_p, and obtaining values for H and S from Table 3.5, a value for RTT may be calculated. (It may be necessary to use interpolation, between given values of P which is 80% of CC.) By selecting a suitable number of cars (L) the interval can then be calculated.

If the calculated interval differs from the value initially selected (and used in equation 3.18), then a new value should be selected and the process repeated until the initial and final values converge. Such iterative procedures require an algorithm for the next trial. A suitable algorithm is to subtract from the initial value twice the difference between the initial and final values.

A suitable initial value can be calculated thus:

$$\text{INT}_i = \text{UPPINT}\left(\frac{A_r}{\text{UPPHC}}\right) \qquad (3.19)$$

Table 3.12 Values of H and S with respect to number of passengers carried in car (P)

(*a*) For 5 to 12 passengers per trip

Number of served floors, N, above MT	H and S values for stated average number of passengers per trip (P)															
	5		6		7		8		9		10		11		12	
	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S
5	4.6	3.4	4.7	3.7	4.8	4.0	4.8	4.2	4.9	4.3	4.9	4.5	4.9	4.6	4.9	4.7
6	5.4	3.6	5.6	4.0	5.7	4.3	5.7	4.6	5.8	4.8	5.8	5.0	5.9	5.2	5.9	5.3
7	6.3	3.8	6.4	4.2	6.5	4.6	6.6	5.0	6.7	5.3	6.7	5.5	6.8	5.7	6.8	5.9
8	7.1	3.9	7.3	4.4	7.4	4.9	7.5	5.3	7.6	5.6	7.7	5.9	7.7	6.2	7.8	6.4
9	8.0	4.0	8.2	4.6	8.3	5.1	8.4	5.5	8.5	5.9	8.6	6.2	8.7	6.5	8.7	6.8
10	8.8	4.1	9.0	4.7	9.2	5.2	9.3	5.7	9.4	6.1	9.5	6.5	9.6	6.9	9.6	7.2
11	9.6	4.2	9.9	4.8	10.1	5.4	10.2	5.9	10.3	6.3	10.4	6.8	10.5	7.1	10.6	7.5
12	10.5	4.2	10.7	4.9	11.0	5.5	11.1	6.0	11.2	6.5	11.3	7.0	11.4	7.4	11.5	7.8
13	11.3	4.3	11.6	5.0	11.8	5.6	12.0	6.1	12.1	6.7	12.3	7.2	12.3	7.6	12.4	8.0
14	12.1	4.3	12.5	5.0	12.7	5.7	12.9	6.3	13.0	6.8	13.2	7.3	13.3	7.8	13.4	8.2
15	13.0	4.4	13.3	5.1	13.6	5.7	13.8	6.4	14.0	6.9	14.1	7.5	14.2	8.0	14.3	8.4
16	13.8	4.4	14.2	5.1	14.5	5.8	14.7	6.5	14.9	7.0	15.0	7.6	15.1	8.1	15.2	8.6
17	14.6	4.4	15.0	5.2	15.3	5.9	15.6	6.5	15.8	7.1	15.9	7.7	16.0	8.3	16.1	8.8
18	15.5	4.5	15.9	5.2	16.2	5.9	16.5	6.6	16.7	7.2	16.8	7.8	16.9	8.4	17.1	8.9
19	16.3	4.5	16.8	5.3	17.1	6.0	17.4	6.7	17.6	7.3	17.7	7.9	17.9	8.5	18.0	9.1
20	17.1	4.5	17.6	5.3	18.0	6.0	18.2	6.7	18.5	7.4	18.6	8.0	18.8	8.6	18.9	9.2
21	18.0	4.5	18.5	5.3	18.8	6.1	19.1	6.8	19.4	7.5	19.6	8.1	19.7	8.7	19.8	9.3
22	18.8	4.6	19.3	5.4	19.7	6.1	20.0	6.8	20.3	7.5	20.5	8.2	20.6	8.8	20.8	9.4
23	19.6	4.6	20.2	5.4	20.6	6.2	20.9	6.9	21.2	7.6	21.4	8.3	21.5	8.9	21.7	9.5
24	20.5	4.6	21.1	5.4	21.5	6.2	21.8	6.9	22.1	7.6	22.3	8.3	22.5	9.0	22.6	9.6

(*b*) For 13 to 20 passengers per trip

Number of served floors, N, above MT	H and S values for stated average number of passengers per trip (P)															
	13		14		15		16		17		18		19		20	
	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S
5	4.9	4.7	5.0	4.8	5.0	4.8	5.0	4.9	5.0	4.9	5.0	4.9	5.0	4.9	5.0	4.9
6	5.9	5.4	5.9	5.5	5.9	5.6	5.9	5.7	6.0	5.7	6.0	5.8	6.0	5.8	6.0	5.8
7	6.9	6.1	6.9	6.2	6.9	6.3	6.9	6.4	6.9	6.5	6.9	6.6	6.9	6.6	7.0	6.7
8	7.8	6.6	7.8	6.8	7.9	6.9	7.9	7.1	7.9	7.2	7.9	7.3	7.9	7.4	7.9	7.4
9	8.7	7.1	8.8	7.3	8.8	7.5	8.8	7.6	8.8	7.8	8.9	7.9	8.9	8.0	8.9	8.1
10	9.7	7.5	9.7	7.7	9.8	7.9	9.8	8.1	9.8	8.3	9.8	8.5	9.8	8.6	9.9	8.8
11	10.6	7.8	10.7	8.1	10.7	8.4	10.7	8.6	10.8	8.8	10.8	9.0	10.8	9.2	10.8	9.4
12	11.6	8.1	11.6	8.5	11.6	8.7	11.7	9.0	11.7	9.3	11.7	9.5	11.8	9.7	11.8	9.9
13	12.5	8.4	12.5	8.8	12.6	9.1	12.6	9.4	12.7	9.7	12.7	9.9	12.7	10.2	12.8	10.4
14	13.4	8.7	13.5	9.0	13.5	9.4	13.6	9.7	13.6	10.0	13.7	10.3	13.7	10.6	13.7	10.8
15	14.4	8.9	14.4	9.3	14.5	9.7	14.5	10.0	14.6	10.4	14.6	10.7	14.6	11.0	14.7	11.2
16	15.3	9.1	15.4	9.5	15.4	9.9	15.5	10.3	15.5	10.7	15.6	11.0	15.6	11.3	15.6	11.6
17	16.2	9.3	16.3	9.7	16.4	10.2	16.4	10.6	16.5	10.9	16.5	11.3	16.6	11.6	16.6	11.9
18	17.2	9.4	17.2	9.9	17.3	10.4	17.4	10.8	17.4	11.2	17.5	11.6	17.5	11.9	17.6	12.3
19	18.1	9.6	18.2	10.1	18.2	10.6	18.3	11.0	18.4	11.4	18.4	11.8	18.5	12.2	18.5	12.6
20	19.0	9.7	19.1	10.2	19.2	10.7	19.3	11.2	19.3	11.6	19.4	12.1	19.4	12.5	19.5	12.8
21	19.9	9.9	20.0	10.4	20.1	10.9	20.2	11.4	20.3	11.8	20.3	12.3	20.4	12.7	20.4	13.1
22	20.9	10.0	21.0	10.5	21.1	11.1	21.1	11.5	21.2	12.0	21.3	12.5	21.3	12.9	21.4	13.3
23	21.8	10.1	21.9	10.7	22.0	11.2	22.1	11.7	22.2	12.2	22.2	12.7	22.3	13.1	22.3	13.5
24	22.7	10.2	22.9	10.8	22.9	11.3	23.0	11.9	23.1	12.4	23.2	12.8	23.2	13.5	23.3	13.8

Example 3.6

Determine the required number of cars (L), interval (INT) and percentage car loading given the following data: N = 16, CC = 16, t_v = 1.0, t_s = 8.0, t_p = 1.2, A_r = 120.

Assuming L = 5 then by conventional calculation:

— RTT = 141.3 s (from equation 3.3)

— UPPINT = 28.3 s (from equation 3.9)

— UPPHC = 135.7 person/5 min (from equation 3.10)

An initial value is calculated from equation 3.19:

$$\text{INT}_i = 28.3 \times 120 / 136 = 25.0 \text{ s}$$

P is then given by:

$$P = 25 \times 120 / 300 = 10$$

This method is illustrated in Table 3.12.

Table 3.12 Iterative calculation of interval (INT)

Parameter	Trial 1	Trial 2
INT_i (s)	25.0	24.2
P	10.0	9.7
H	15.0	15.0
S	7.6	7.4
RTT (s)	122.8	120.5
L	5	5
INT_f (s)	24.6	24.1†
New INT_i = INT_i – 2(INT_i – INT_f):		
New INT_i	24.2	–
Car load (%)	61.0	–

† Further trials unnecessary since difference between INT_i and INT_f is less than 1%

In Example 3.6 a balance between arrivals and lift system handling capacity occurred at an INT of 24.1 s and a car loading of 61%. Contrast this with an UPPINT of 28.3 s at an 80% car loading. It is important to remember that the best design, which is a compromise between capital cost and passenger waiting times, is an 80% car loading.

3.8.6 Rated speed and interfloor height — effect on assumed flight time

It is commonly assumed that rated speed is reached in the distance of a single floor jump only with slow speed lifts and/or large interfloor distances. As a rule of thumb this means for speeds less than 1.6 m/s with a 3.3 m interfloor distance. Hunt[14] presents an example of speed/time curves for a 5 m/s rated speed and 1.5 m/s² acceleration, where the rated speed is reached only after a flight of seven floors. However, the derivation of the RTT assumes that all movements larger than one interfloor distance are made at rated the speed. The resulting errors may be determined from Table 3.14 as follows.

In Table 3.14, the second column gives the measured flight times for a rated speed of 4.0 m/s over an interfloor distance of 3.2 m. These values have been chosen so that t_v is 0.8 s. The rated speed will be reached at a distance of 14.8 m (i.e. between floors 4 and 5). Thereafter the increment in flight time for each additional floor is 0.8 s. However, the RTT calculation assumes 0.8 s is added to the $t_{f(1)}$ value of 4.0 s for every floor jumped, as given in the third column. The fourth column gives the resulting error. This additional time will affect the value used for t_s.

Table 3.14 Flight time error

Floor number n	Measured flight time $t_{f(n)}$ (s)	Assumed flight time (s)	Error (s)
1	4.0	4.0	0.0
2	5.2	4.8	0.4
2	6.2	5.6	0.6
4	7.0	6.4	0.6
5	7.7	7.2	0.5
6	8.5	8.0	0.5
7	9.3	8.8	0.5
8	10.1	9.6	0.5

Unequal floor heights also affect the assumption made for $t_{f(1)}$ and usually increase the distance to be travelled.

Both effects can be taken into account as follows:

(*a*) Determine the distance d_H to reach reversal floor H, including all irregularities of interfloor heights.

(*b*) Determine the average distance between stops by dividing height to H by S.

(*c*) Divide by d_f to determine the average number of floors between stops represented by this distance.

(*d*) A table similar to Table 3.14 for the system under consideration may be used to determine the actual flight time to travel this distance.

(*e*) Calculate the difference between this time and the assumed time.

(*f*) The error in RTT is (S+1) times this time difference.

Example 3.7

Figure 3.8 shows a 16-floor building which has three floors which are not of standard interfloor height:

— main floor (lobby): $2.0 \times d_f$

— floor 4 (conference room): $1.5 \times d_f$

— floor 8 (service area): $1.5 \times d_f$

Other design data are: CC = 16, H = 15.3, S = 9.0, d_f = 3.2, v = 3.15, T = 9.0, t_p = 1.2, $t_{f(1)}$ = 5.0, $t_{f(2)}$ = 6.5. Determine the error in RTT.

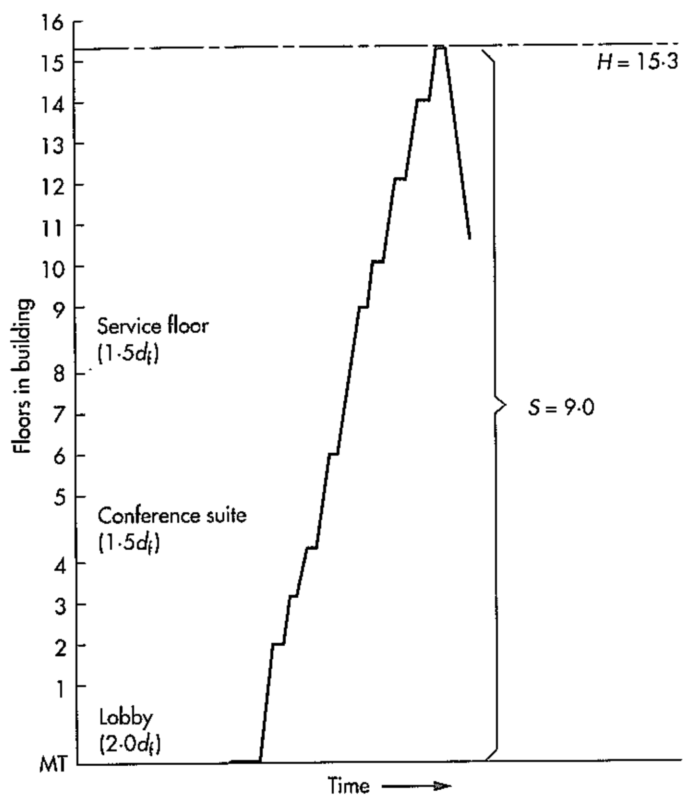

Figure 3.8 Example 3.7: building with unequal interfloor heights and interfloor jumps greater than single floor

First calculate RTT from Table 3.11:

— RTT is given as 147.1 s

— correct for T = 9.0 by subtracting 10.0 s

— correct for t_p = 1.2 by adding 5.1 s

— correct for d_f = 3.2 by subtracting 0.7 s (i.e. 0.1/0.33 × 2.2)

Therefore:

$$\text{RTT} = 147.1 - 10.0 + 5.1 - 0.7 = 141.5 \text{ s}$$

Height of building d_H to reach highest reversal floor (H) is calculated by adding the extra height (i.e. heights over d_f) of the lobby floor and floors 4 and 8 to ($H\,d_f$), thus:

$$d_H = (15.3 \times 3.2) + (2 - 1)\,3.2 + 2\,(1.5 - 1)\,3.2$$

$$= 55.4 \text{ m}$$

Average distance between stops:

$$d_H / S = 55.4 / 9.0 = 6.16 \text{ m}$$

Average number of floors between stops:

$$6.16 / d_f = 6.16 / 3.2 = 1.93$$

Since 1.93 is not an integer number of floors it is necessary to interpolate between the values for $t_{f(1)}$ and $t_{f(2)}$ given above. This gives the average jump time as 6.4 s.

Assumed average jump time is given by $t_{f(1)}$ plus the time taken to travel 0.93 floors at 3.15 m/s, i.e:

$$5.0 + (0.93 \times d_f / 3.15) = 5.94 \text{ s}$$

Therefore flight time error is:

$$6.4 - 5.94 = 0.46 \text{ s}$$

Error in RTT is given by:

$$(S + 1) \times 0.46 = 10 \times 0.46 = 4.6 \text{ s}$$

Thus:

$$\text{RTT} = 141.5 + 4.6 = 146.1 \text{ s}$$

This represents an error in RTT of about 3% in this case.

3.8.7 Traffic controller

The traffic control system (or despatcher) is assumed to be ideal. During the up-peak the controller is programmed to bring cars to the main terminal floor immediately after the last passenger exits from the car at the highest demanded floor (H).

On older scheduled (i.e. timed) systems, it is possible for the wrong control algorithm to be switched on for the prevailing traffic pattern. For example, the down-peak algorithm during up-peak. Older scheduled controllers used a despatch interval to maintain a headway between cars leaving the main terminal. This was designed to space cars equally around the building but, during the up-peak, it has the effect of reducing the handling capacity by delaying the departure of loaded cars from the main terminal. The despatch interval was often set at the theoretical value of the UPPINT, say 30 s, so its effect can be significant. With this type of controller it is recommended that the RTT be increased by 15%.

Modern on-call controllers utilise traffic load and direction detection systems to determine the prevailing traffic pattern. The difficulty with these controllers is that sometimes the change of traffic pattern is detected too late to be effective. All types of controller (except hall call allocation controllers) have this problem and some designers add 10% or 15% to the RTT to account for this inefficiency. This is a reasonable correction, provided it is added to all prospective designs and the figure used is known to all parties.

Hall-call allocation control systems employ a hall call registration panel which permits passengers to indicate their destination floor. This enables the computer-based controller to ensure that passengers requesting the same destination floors use the same car and hence reduce the number of stops made by each car. Closs[15] claims an increase of handling capacity of between 25% to 33% and Schroeder[16] indicates an improvement of between 40% and 60%. However, until more is known about this generation of controllers, it is recommended that the RTT be reduced by only 25% when using this type of controller.

The effect of different control system techniques during up-peak have been tabulated by Barney[17] for values of handing capacity, passenger average waiting time, passenger average journey time and car loading.

Most control systems use a loading interval at the main terminal floor during up-peak. This prevents the car from responding immediately to the first call registered and hence leaving with only one or two passengers. This loading interval is effectively the time for a reasonable number of passengers to board the car and should therefore overlap the boarding part of the passenger transfer time. Thus the loading interval should be set to the time it would take for the car to become 60% to 80% loaded. There will then be no effect on the RTT calculation due to loading interval.

Some control systems cause the car doors to remain open for a fixed period of time after the car has arrived at a floor to enable passengers to enter or leave the car without the doors closing on them. This is unnecessary where passenger detection systems are fitted because the doors will close only when the threshold is clear of passengers. Where a door dwell time is operating it may be longer than the assumed passenger transfer time and in such cases extra time must be added to the last term in the RTT equation.

Typically door dwell times are 2 s for a car call stop and 3 s for a hall call stop. (The extra time used for hall calls is to allow passengers waiting at the opposite end of a group to walk to the arriving car's position; this is not relevant during up-peak.) In residential buildings it is common to set the door dwell time to 7 s to allow for prams and bicycles to be manoeuvred in and out of the lift. The effect on the RTT value can be easily accommodated.

3.9 Estimation of passenger average waiting time during up-peak

Passenger waiting time is the time an individual passenger waits at a floor before being able to board a lift. It is advisable to determine the average passenger waiting time for each car load of passengers in order to obtain statistically significant figures.

Average passenger waiting time is not dependent solely on UPPINT but is also affected by the average car load and the arrival probability distribution function. The relationship between the car load and its associated interval (INT) are as shown in Figure 3.5. The car load and INT can be determined using the procedure given in section 3.8.5.

Figure 3.5 and Table 3.3 enable an estimate of the average passenger waiting time to be made. In Figure 3.5 average waiting time (AWT) is normalised by dividing it by INT to give a performance figure against percentage car load as the independent variable. The solid line gives an average value and the dotted lines indicate the probable range of values. This latter aspect accounts for the range of building and lift system (including traffic controller) parameters, and passenger demands. Table 3.3 provides the graphical values in tabular form.

Example 3.8

Estimate the average passenger waiting time for the circumstances described in Example 3.6.

From Example 3.6 (see Table 3.12):

— car load is 61%

— interval is 24.1 s

From Table 3.3 for 61% car load, by interpolation:

$$\text{AWT} / \text{INT} = 0.515$$

Therefore, for interval of 24.1 s, average passenger waiting time is:

$$\text{AWT} = 0.515 \times 24.1 = 12.4 \text{ s.}$$

3.10 Other traffic conditions

3.10.1 General

The up-peak traffic pattern is well defined but, in practice, it is rarely as simple as has been suggested. Often there will be some downward travel and interfloor traffic during the up-peak period and some designers attempt to include these in their calculations. However, with the wide range of possible assumptions no general benchmark condition can be defined. Therefore it is recommended that all up-peak calculations are carried out on the assumption that the up-peak is 'pure' and this may then be used as a benchmark to compare different designs and tenders.

During down-peak traffic there may also be some up-peak and interfloor activity. It is possible to derive equations for down-peak in the same way as for up-peak but a simpler method is given in section 3.10.2.

True interfloor activity will be completely random (i.e. no obvious pattern of calls) and balanced so that no floor either gains or loses population over a period of several hours. Again, equations can be developed but they are of limited use due to the wide range of possibilities. Alexandris *et al.*[18] have derived complex formulae for the most general case of interfloor traffic with unequal floor demands and unequal floor populations. An easier method of analysis is shown in section 3.10.3.

The guidance given in sections 3.10.2 and 3.10.3 uses a technique of discrete digital simulation[6] to analyse a representative number of lift configurations to derive empirically the important design criteria.

3.10.2 Down-peak traffic design

The pattern of car movements are characterised by the 'down staircase' pattern of floor stops shown in Figure 3.9. The cars stop less often than during the up-peak and the interval at the main terminal is smaller. Digital computer simulation confirms both these observations as shown in Figure 3.10.

In Figure 3.10, the independent axis relates to the percentage down-peak demand (D_d):

$$D_d = A_r / \text{UPPHC} \times 100 \qquad (3.20)$$

where UPPHC is calculated for an 80% car loading and A_r is the passenger arrival rate in persons per five minutes.

Thus, when D_d is 150%, this is equivalent to one and a half times the up-peak demand which is a typical down-peak handling requirement.

The solid line on Figure 3.10(a) shows the average down-peak interval (DNPINT) normalised by dividing it by UPPINT to give a percentage relationship. Figure 3.10(a) shows that the DNPINT is about 67% of the UPPINT, thus confirming the inherent extra handling capacity available in a given lift system during down-peak.

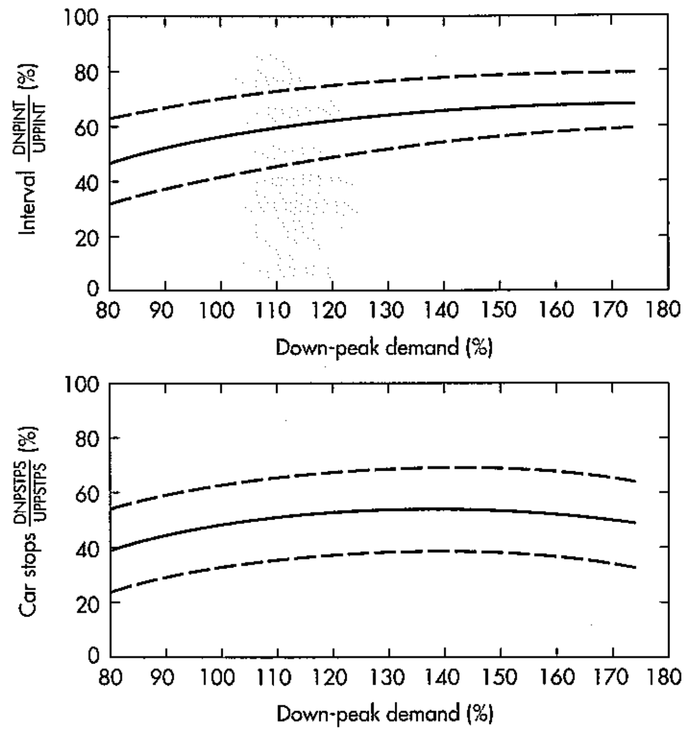

Figure 3.10 Down-peak traffic design; (a) percentage interval, (b) percentage number of car stops

The solid line on Figure 3.10(b) relates the average number of down-peak stops (DNPSTPS) to up-peak stops (UPPSTPS) and indicates that the number of down-peak stops are about 50% of the up-peak stops. This is because during down-peak cars tend to load fully at a few floors only.

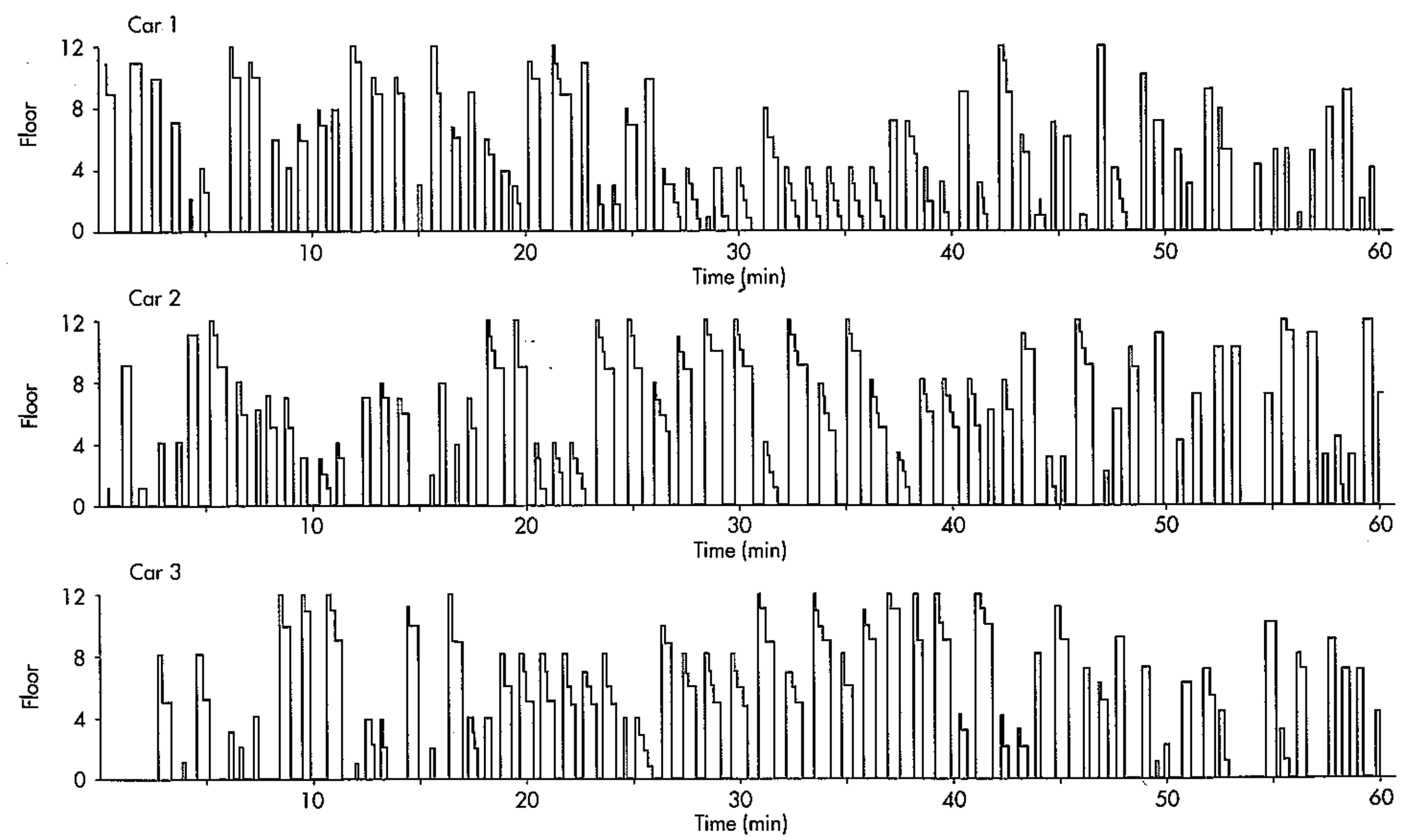

Figure 3.9 Car movements during down-peak traffic

An indication of the quality of service during down-peak is given in Figure 3.11. Here passenger average waiting time (AWT) is shown as a ratio of UPPINT against down-peak demand.

The straight line is the average of many lift configurations and control systems and represents the relationship:

$$\text{DNAWT} = \text{UPPINT} \times 0.85 \times D_d / 100 \qquad (3.21)$$

where DNAWT is the down-peak average passenger waiting time and D_d is the down-peak demand.

The broken lines in Figures 3.10 and 3.11 indicate the probable range of the various parameters about the average. The traffic controller has a greater influence during down-peak than up-peak. Its effect can be seen in Figure 3.9 where the cars may be seen to be despatched to different levels of the building. This cycling of the cars ensures an even service at all floors. If all cars returned to the highest floor they would be filled by the time they reached the lower floors.

Barney and Dos Santos[19] have shown that the various types of traffic control algorithms exhibit different properties. The main types are:

- fixed sectoring, common sectors
- fixed sectoring, priority timed
- dynamic sectoring
- estimated time of arrival
- self-tuning
- hall-call allocation.

There is no clear best down-peak traffic control algorithm as some algorithms work well at low demands while others work well at high demands. No simple recommendation can be made and it is necessary to study all the likely circumstances.

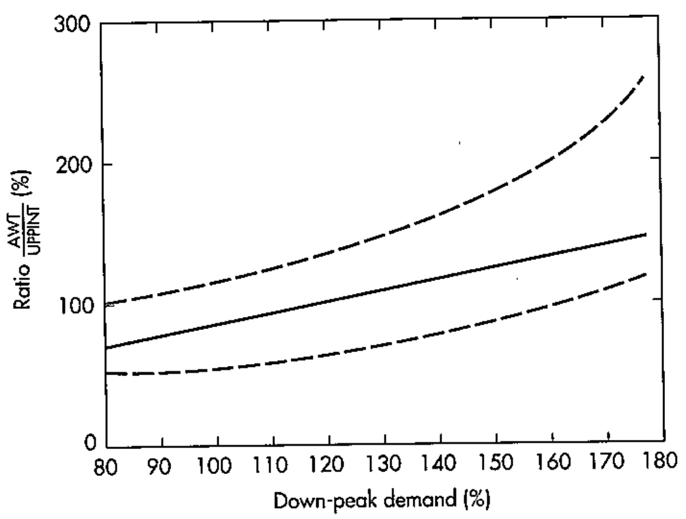

Figure 3.11 Down-peak performance

3.10.3 Interfloor traffic design

There is no discernible pattern of movement during interfloor traffic, see Figure 3.12. The concept of an interval has no meaning during interfloor traffic as round trips do not always pass through the main terminal. An indication of the quality of service is shown in Figure 3.13 in which the ratio AWT/UPPINT (expressed as a percentage) is plotted against interfloor demand D_i.

In Figure 3.13 the independent axis relates to the percentage interfloor demand (D_i), i.e:

$$D_i = A_r \times 100 / \text{UPPHC} \qquad (3.22)$$

Bedford[20], working with a fixed sectoring priority timed algorithm, suggests that 2.25 stops per car per minute is typical of the values for D_i expected for busy or heavily loaded systems. This is equivalent to about one half of the population of a building using the lifts in one hour with an average waiting time of about half that endured during the up-peak.

For design purposes, it is recommended that an average busy system should be considered as one in which one third of the building's population uses the lift system in one hour. Thus if 36% of a building's population used the lifts in one hour this would be equivalent to an A_r of 3% of the building's population in a five minute period.

The broken lines indicate the probable range of values. A straight line can be fitted to the average of similar plots for many lift configurations and control systems which has the relationship:

$$\text{IFAWT} = \text{UPPINT}\,(0.22 + 1.784\,D_i / 100) \qquad (3.23)$$

where IFAWT is the interfloor passenger average waiting time.

The traffic controller has a considerable influence on interfloor traffic performance. At high demand levels the fixed sectoring systems perform less well than either dynamic sectoring or modern computer-based algorithms. However, at interfloor demands below 30% the differences are only a few percent.

3.10.4 Estimation of down-peak and interfloor performance

It is possible to estimate down-peak and interfloor performance for an average lift system using the techniques described in sections 3.10.2 and 3.10.3. However, the values obtained should be used only for guidance or comparison purposes as they are average values with a wide band of variability.

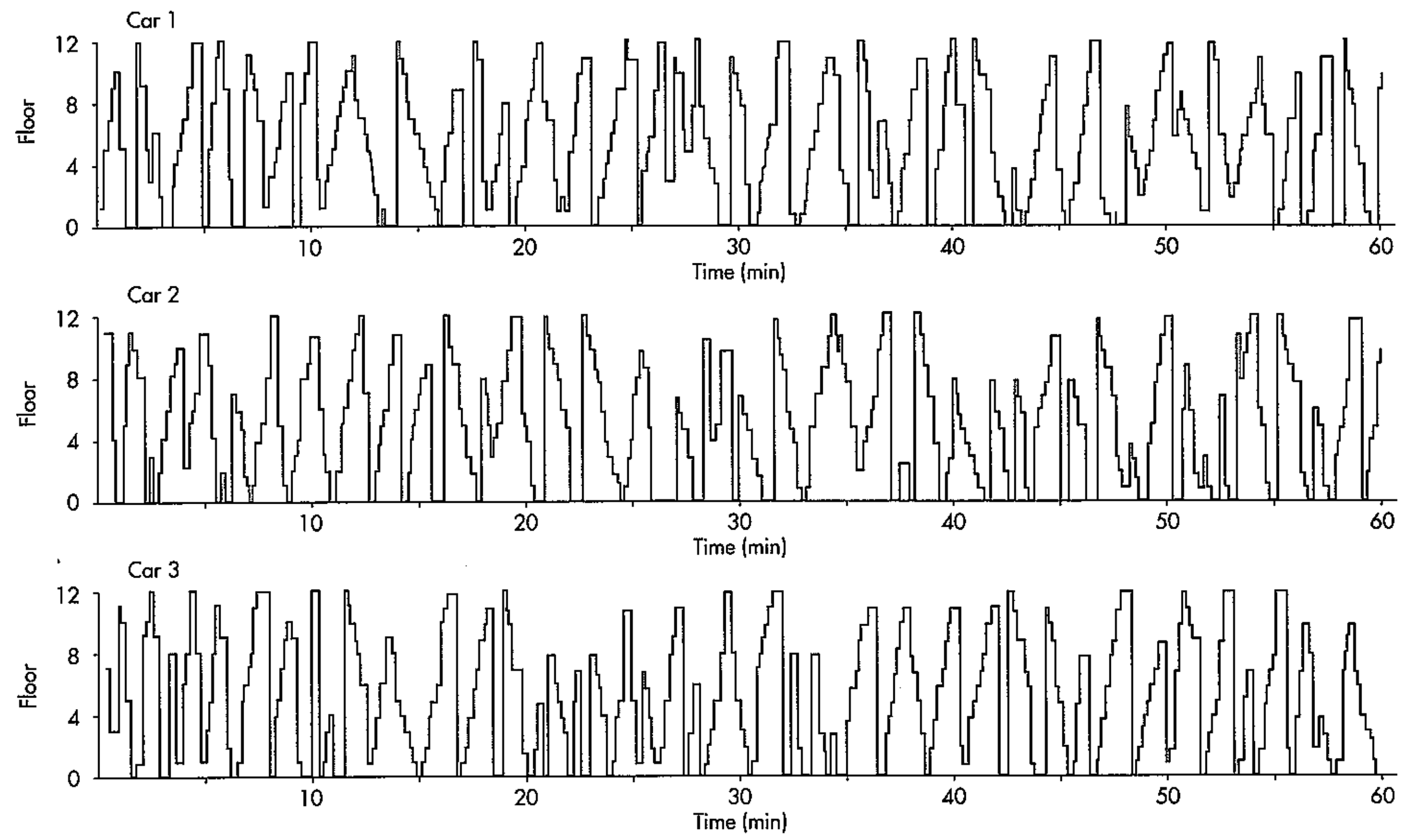

Figure 3.12 Car movements during interfloor traffic

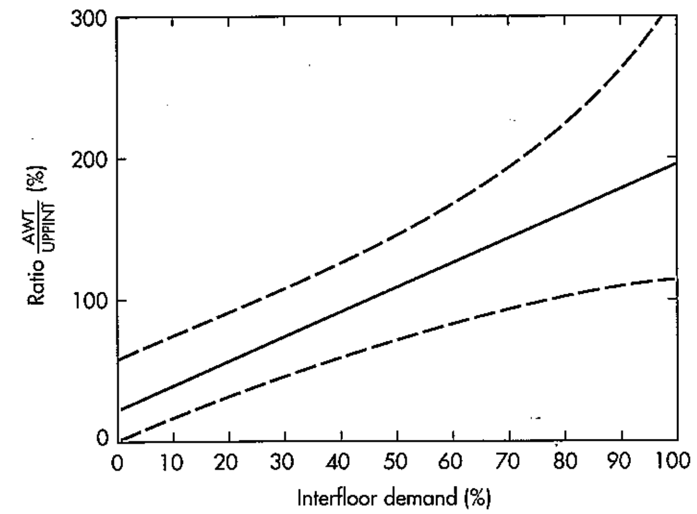

Figure 3.13 Interfloor performance

Example 3.9

Figure 3.14 shows the measured traffic pattern for a lift system. Determine the passenger average waiting times for up-peak, down-peak and interfloor traffic conditions. Relevant data for the system are: $N = 16$, $L = 5$, CC $= 16$, $P = 1250$, $t_v = 1.1$, $t_s = 8.3$, $t_p = 1.0$, $v = 3.15$.

Floor-to-floor cycle time (T) is given by:

$$T = t_s + t_v = 9.4 \text{ s}$$

Then, using Table 3.11:

$$\text{RTT} = 147.1 - 6.0 = 141.1 \text{ s}$$

Therefore, from equation 3.9:

$$\text{UPPINT} = 28.2 \text{ s}$$

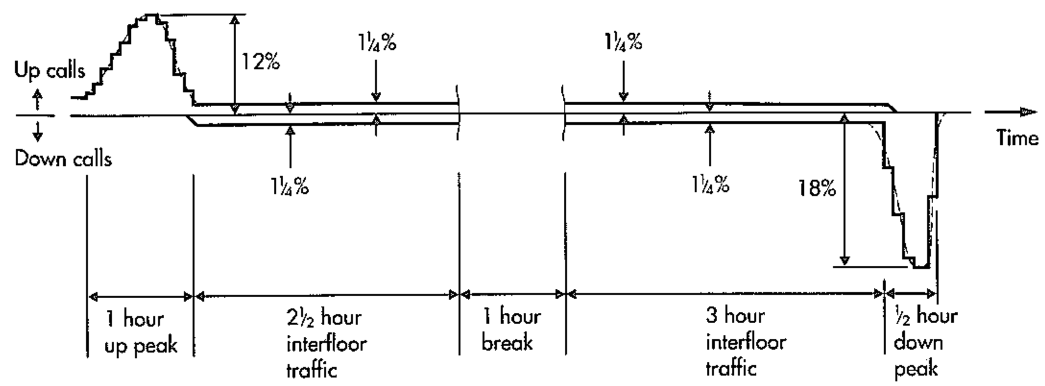

Figure 3.14 Example 3.9: measured traffic pattern (percentages are passenger arrival rates per 5 min period)

From equation 3.10:

$$\text{UPPHC} = 136.2 \text{ person/5 min}$$

Assuming the effective population (U) is 80% of the total population (P), U = 1000. Then, from equation 3.12:

$$\%\text{POP} = 136.2 / 1000 = 13.6\%$$

(a) Up-peak calculation

As UPPHC is greater than the 12% up-peak demand (see Figure 3.14) to be served, the iterative procedure given in section 3.8.5 must be used to calculate INT and load.

Estimate a suitable initial interval for trial 1 using equation 3.19:

$$\text{INT}_{\text{i}} = 28.2 \times 120 / 136.2 = 25 \text{ s}$$

This is the same initial interval that was used in Example 3.6. Table 3.10 gives INT as 24.1 s and car load as 61%.

Thus, using Table 3.3:

$$\text{UPPAWT} = 0.515 \times 24.1 = 12.4 \text{ s}$$

(b) Down-peak calculation

From Figure 3.14, the down-peak demand is 18% of the effective population. Therefore using equation 3.20:

$$D_{\text{d}} = 180 \times 100 / 136.2 = 132.2\%$$

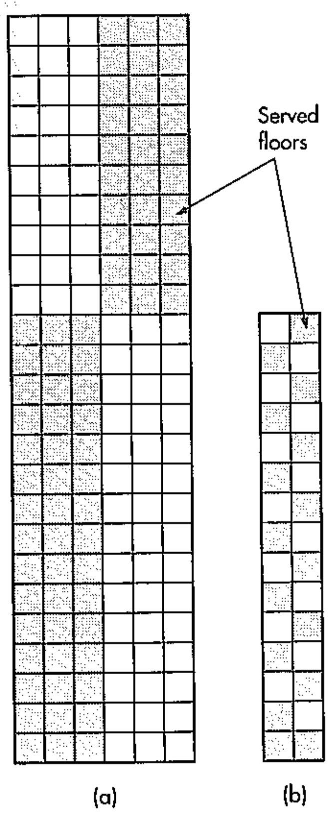

Figure 3.15 Building zones; (a) stacked, (b) interleaved (floors served within each zone shown shaded)

Then using equation 3.21:

$$\text{DNAWT} = 28.2 \times 0.85 \times 132 / 100 = 31.6 \text{ s}$$

(c) Interfloor calculation

The interfloor demand is 2.5% of the effective population (equivalent of 30% of the building population using the lifts every hour).

Using equation 3.22:

$$D_{\text{i}} = 25 \times 100 / 136.2 = 18\%$$

Then using equation 3.23:

$$\text{IFAWT} = 28.2\,(0.22 + 1.784 \times 18 / 100) = 15.0 \text{ s}$$

3.11 Further considerations in planning and selection of systems

3.11.1 Tall buildings

Table 3.5 shows that, for a specified car size, the number of stops (S) increases as the number of served floors (N) increases. The round trip time (RTT) is dominated by the central term in equation 3.3, which includes S. Therefore, as the number of stops increases, RTT increases which, in turn, increases the up-peak interval, the passenger waiting time and the passenger journey time. A similar deterioration of performance occurs for other traffic conditions.

The solution is to limit the number of floors served by the lifts by dividing the building into zones such that each lift or group of lifts is constrained to serve a designated set of floors. A rule of thumb is to serve a maximum of 16 floors with any one lift or a group of lifts. There are two forms of zoning, known as stacked and interleaved, and these are shown in Figure 3.15.

Note that the term 'zone' is sometimes used to mean sectors in a traffic control system. Sectors are used in the implementation of a traffic controller algorithm and also define a designated, but smaller, set of floors. There may be as many sectors in a zone as there are cars to serve that zone.

The introduction of groups of lifts to serve different zones of a building requires more space at the main terminal level. The positioning of the groups is important and adequate signs should be displayed to quickly and simply direct the passengers to the correct group. The arrangement of lifts within each group is given in Figure 2.4.

3.11.1.1 Stacked zones

A stacked zone building is one divided into horizontal layers which, in effect, is the equivalent of stacking several buildings on top of each other, with a common plan area in order to save ground space. It is a common and recommended practice for office and institutional buildings.

Each zone can be treated differently with regard to lobby arrangements (i.e. shared or separate), grade of service, etc. The number of floors in a zone, the number of lifts serving a zone and the length of the express jump all affect the RTT. The RTT can be adjusted by adding a time equal to the time taken to jump through the unserved floors in both directions. This is illustrated in Example 3.10.

Example 3.10

A 36-floor building is to be served by 16-person cars. All zones are to have an equivalent grade of service. Produce designs for two systems, one with equal numbers of cars and the other with equal numbers of floors. Assume identical values for T, t_{p}, etc.

Table 3.15 shows a design for an equal number of cars, with a decreasing number of floors in each zone. This is an attempt to equalise the RTTs at the main terminal (MT) by compensating for the express jumps (MT to floor 15, MT to floor 27) by reducing the number of floors to be served.

Table 3.16 shows a system serving an equal number of floors, with an increasing number of cars to compensate for the time to transit the unserved express jumps. There are a wider range of values for UPPINT. It is usually easier to adjust the number of floors per zone than the number of lifts per zone.

Table 3.15 Equal numbers of cars

Zone	Number of floors	Served floors	Number of cars	Speed (m/s)	UPPINT (s)
Low	14	1–14	6	2.50	24.0
Middle	12	15–26	6	3.15	24.3
High	10	27–36	6	4.00	23.5

Table 3.16 Equal numbers of floors

Zone	Number of floors	Served floors	Number of cars	Speed (m/s)	UPPINT (s)
Low	12	1–12	5	2.50	26.9
Middle	12	13–24	6	3.15	23.9
High	12	25–36	7	4.00	21.1

3.11.1.2 Interleaved zones

For interleaved zoning, the lifts are required to serve either even floors or odd floors. This is common practice in local authority housing.

The effect is to reduce the number of stops made by a car because there are fewer floors to be served. This also reduces the capital cost because there are fewer openings and landing doors. However, the service to passengers is poorer than that for a duplex system serving all floors because there is only one car to take them to the required floor.

Tenants tend to solve this problem by calling both cars simultaneously to the main terminal and, if the 'wrong' car arrives first, walking a flight of stairs to their required floor. Thus cars are unnecessarily brought to the main terminal.

Furthermore, it has been shown[21] that the landing doors perform 70% more operations than where the cars stop at all floors. This is likely to cause an increased level of maintenance call-backs to the most troublesome component of the system.

When calculating the RTT for an interleaved-zoned building, it is essential to remember that the interfloor distance is twice the standard spacing leading to an increased 'single floor' flight time.

For the above reasons, interleaved zoning is not recommended.

3.11.2 Very tall buildings

Very few very tall buildings (i.e. over 40 storeys) are built in Britain therefore traffic design for such buildings is not considered here. A review of the US practice is given by Fortune[22].

3.11.3 Service of basement floors

Buildings are often designed with car parks, or some service facility such as a restaurant or leisure area, below the main terminal at basement level.

Often not all of the lifts serve areas below the main terminal. While this saves capital expenditure, it is not recommended since it contradicts the convention that all lifts in a group should serve the same floors. Passengers will experience difficulty in selecting which of the lifts within a group serve the basement, unless special signalling arrangements are made.

It may be better to serve the basement by providing a separate lift, since there should always be one lift serving all levels (e.g. for safety reasons and goods handling). Provision of such a lift will avoid seriously detracting from the traffic handling capabilities of the main group. In the event that only one lift within a group serves all floors, the waiting time experienced by passengers will be long (almost the round trip time).

During interfloor traffic there will be no appreciable deterioration in service. During up-peak and down-peak, however, the loss of cars below the main terminal will affect service.

During the up-peak traffic condition the presence of a served basement will introduce, at best, one extra stop (if the main terminal is bypassed on the way down) and, at worst, two extra stops (if the lift stops at the main terminal on the way down and again on the way up). The second circumstance will arise if passengers press both buttons at the main terminal, as is often the case, in the mistaken belief that this will ensure that the lift arrives more quickly. The outcome is passenger loading delays at the main terminal as passengers try to decide whether to enter a car going down or wait for a car going up. Another effect of service to the basement area during up-peak is that cars arrive at the main terminal already partly full, thus causing more confusion.

The time penalty for the extra stops can be between 10 s and 20 s and between 5 s to 10 s for the increased passenger loading times, i.e. in total, some 15 s to 30 s to be added to the RTT. In the case of a 16-person car serving 16 floors with a RTT of 150 s, the extra time will add 10% to 20% to the RTT.

During the down-peak a downward trip below the main terminal to visit, say, basement leisure facilities will add one extra stop plus the extra time required to transit the extra interfloor distance, say 10 s to 12 s. This will reduce the handling capacity during down-peak.

Designers must take account of these factors, when sizing an installation with served levels below the main terminal. Nahon[23] has indicated that, where there are many floors below the main terminal, the probable stops and reversal floors may be calculated in a similar way to that for the upward service. The resulting additional time can then be added to the normal RTT.

3.11.4 Multiple entry floors

Some buildings have main entry points at more than one level. The effect of more than one main terminal is disruptive and, in the interests of efficient circulation, buildings should not be designed in this way. If there is more than one entrance, means should be provided to bring the two routes together at a lift lobby.

Except in special cases it is recommended that the main terminal floor should be used as an interchange for the different circulation modes. Service to and from basement levels should be by means of well designed stairways, escalators or short-rise lifts (perhaps hydraulic). If this is not possible sizing of the lift system should take into account the extra times incurred stopping and loading at multiple floors.

3.11.5 Hotels

The traffic patterns in hotels are complex and cannot be compared to the morning and afternoon peaks in office buildings. The most highly loaded times are at check-out (8.00 to 10.00 a.m.) and check-in (5.00 to 7.00 p.m.). At these times heavy, two-way traffic occurs with guests entering and leaving the hotel plus interfoor traffic as guests move between the lobby, guest rooms and restaurants. Therefore, calculations should assume equal numbers of up and down stops at these times.

Cars are unlikely to be more than 50% loaded. The car sizes should also carry 16 or more persons to accommodate luggage and ensure that the guests do not have to experience crowded conditions.

As a rule of thumb, assume one lift for every 90 to 100 keys. This rule must be used with care as it would not be suitable for, say, a low-rise hotel with 30% of its rooms on the entrance level, nor for a high rise hotel with a small plan area.

It is recommended that the service traffic (baggage, goods, room service, messengers, etc.) be served by a secondary vertical transportation system, leaving the main lifts for the guests.

3.11.6 Hospitals

Most hospitals in the UK are low-rise, so the problems with operating theatre emergencies are not so serious as those in the USA. However, it is important to ensure that bed lifts are separated from visitor and staff movements.

3.11.7 Shopping centres

Most shopping centres provide two or three levels of shops with several levels of car parking either above or below the retail area. Therefore, consideration must be given to both circulation in the retail area and access to and from the car parks.

In the retail area, shoppers can be encouraged to use well indicated stairways, as most movements will be from one floor to the next. In addition, escalators should be provided at crossing points between malls. Observation lifts are often provided not only for transportation but also as for the enjoyment of shoppers. These lifts are usually hydraulic with slow flight times and slow door times. The traffic handling in a shopping centre is eased by the enjoyment aspects and the many modes of movement available.

In many cases the number of shoppers using the car park lifts is determined from the maximum rate of entry of cars and their average occupancy. These figures are usually determined from an associated (road) traffic study such as that given in Greater London Council study *GLC 25*[4].

As a rough guide, assume lift capacity for one person is required for every 100 m^2 of gross lettable retail area. So a 4 000 m^2 store requires two 20-person cars. Lifts should always be located in pairs rather than singly in order to provide an interval of 40 to 60 s. It is unlikely that the lifts will fill to more than 50% and even less if trolleys are available.

3.11.8 Goods lifts

The need for goods lifts has increased substantially in recent years. The amount of paper needing to be moved into or out of office buildings has increased, largely due to the increased use of computers. Also, in all types of building, it is common to find one or more floors under refurbishment with the requirement to bring in equipment and to remove rubbish and building work debris.

All buildings should be served by an adequate number of goods lifts of a suitable size. This will ensure that the passenger lifts are used for their designed purpose and not abused by being required to serve as goods lifts, to the detriment of the passenger service.

It is recommended that all mid- to high-rise office buildings contain at least one dedicated goods lift, particularly if the building is designed for a single tenant occupancy. The following points should be noted:

- for office buildings with gross total floor area approaching 30 000 m^2, provision should be made for one dedicated goods lift
- for larger buildings, an additional goods lift should be provided for each additional 40 000 m^2 gross floor area
- dedicated goods lifts should have a minimum capacity in the range 1600–2000 kg.

3.11.9 Observation lifts

Observation lifts are often installed in hotels and shopping malls as a feature to provide visual impact. They will, naturally, draw a large percentage of 'joyriders'. Even under these conditions observation lifts contribute to the vertical transportation system of a building. However, because they generally have longer flight and door times, and because the car interiors are shaped for viewing the surroundings rather than for circulation within the car, they should be considered as having a much reduced handling capacity compared with conventional lifts.

3.12 Complete design example

3.12.1 Description of design problem

A regular (i.e. not 'prestige') speculative building with 10 served floors (above the main terminal) is to be built. Each floor has 1200 m^2 of net space. The standard interfloor distance is 3.3 m. Other data will be introduced at appropriate points.

3.12.2 Passenger demand

Speculative buildings are often occupied by more than one tenant, i.e. multiple tenancy.

Table 3.1 indicates 10–12 m^2/person should be assumed per floor. Therefore, assume 12 m^2. The population per floor will be:

$$1200 / 12 = 100 \text{ persons per floor}$$

The total population will be:

$$10 \times 100 = 1000 \text{ persons}$$

Assume 80% daily occupancy (see section 3.3.4). Therefore, the design population is 800 persons.

Table 3.2 indicates that 11–15% of the population will arrive during the busiest five minutes of the morning up-peak; assume 12.5%. Then the peak arrival rate will be:

$$0.125 \times 800 = 100 \text{ persons}$$

Table 3.2 indicates an interval for cars arriving at the main terminal of 25 to 30 seconds. For a speculative building, to reduce capital expenditure, assume 30 s.

Thus, the lift system should be sized to be able to handle 100 persons in 5 minutes with a 30 second interval.

3.12.3 Initial sizing

The object is to estimate the car size required to handle 100 persons in 5 minutes with an up-peak interval of 30 s.

Number of trips in 5 minutes (i.e. 300 seconds):

$$300 / 30 = 10$$

Number of persons per trip:

$$100 / 10 = 10$$

From equation 3.8 (section 3.4), required car size is:

$$10 / 0.8 = 12.5$$

BS 5655: Part 5[24] gives the nearest standard car size as 13 persons.

3.12.4 Calculation of handling capacity

It is first necessary to determine the RTT using equation 3.3, see section 3.4, i.e:

$$\text{RTT} = 2\,H\,t_v + (S + 1)\,t_s + 2\,P\,t_p$$

Values must now be determined for the parameters given in this equation.

Total travel is:

$$3.3 \times 10 = 33 \text{ m}$$

From Table 3.7, rated speed will be 1.6 m/s. Therefore transit time (t_v) is given by:

$$t_v = 3.3 / 1.6 = 2.1 \text{ s}$$

Table 3.7 indicates a likely single floor flight time ($t_{f(1)}$) of 6.0 s.

From Table 3.8, select centre-opening doors 1.1 m wide, giving a door opening time (t_o) of 0.8 s and a door closing time (t_c) of 3.0 s.

From equations 3.5 and 3.6, time consumed in making a stop (t_s) is given by:

$$t_s = 6.0 - 2.1 + 0.8 + 3.0 = 7.7 \text{ s}$$

Using equation 3.8, as 13-person cars are to be used, the average number of passengers (P) will be:

$$P = 13 \times 0.8 = 10.4 \text{ persons}$$

From Table 3.5, the value for the average highest reversal floor (H) is 9.5 and the average probable number of stops (S) is 6.7.

Assume a passenger transfer time (t_p) of 1.2 s, then equation 3.3 gives:

$$\text{RTT} = (2 \times 9.5 \times 2.1) + (6.7 + 1)\,7.7$$

$$+ (2 \times 10.4 \times 1.2)$$

$$= 39.9 + 59.3 + 25.0 = 124.2 \text{ s}$$

An up-peak interval (UPPINT) of 30 s is required, therefore use 4 cars.

The up-peak interval is obtained from equation 3.9 i.e:

$$\text{UPPINT} = 124.2 / 4 = 31.1 \text{ s}$$

The 5-minute up-peak handling capacity (UPPHC) is obtained from equation 3.11, i.e:

$$\text{UPPHC} = (300 / 124.2) \times 10.4 \times 4$$

$$= 100.5 \text{ person/5 min}$$

3.12.5 Variation for zoned building

Suppose that the 10 floors considered above comprise the upper zone of a 25-floor building. The first served floor of the upper zone is now floor 16, with a travel of 63 m (i.e. lobby atrium and service floors increase the travel).

Suppose that the first served floor (floor 16) has a height of 6 m and that there is a service floor of 5 m height between floors 20 and 21. The interfloor distance for the remaining 8 floors is 3.3 m.

The total building height is given by:

$$63 + 6 + 5 + (8 \times 3.3) = 100.4 \text{ m}$$

Therefore, from Table 3.7, the rated speed will be 5 m/s. Table 3.17 lists suitable flight times.

Table 3.17 Flight times

Number of floors jumped	Flight time (s)
1	4.50
2	5.68
3	6.60
4	7.39
5	8.08
6	8.70

Note: After a jump of 6 floors the rated speed is attained; flight times increase by 0.66 s (i.e. interfloor distance divided by rated speed) for each floor jumped thereafter

Thus, from equation 3.4, t_v becomes:

$$t_v = 3.3 / 5 = 0.66 \text{ s}$$

From equations 3.5 and 3.6, t_s becomes:

$$t_s = 4.50 - 0.66 + 0.8 + 3.0 = 7.64 \text{ s}$$

The value for H (i.e. 9.5) must be increased by 15 to account for the express zone jump; S is unchanged (i.e. 6.7).

Using equation 3.3, RTT now becomes:

$$\text{RTT} = 2 \times (9.5 + 15)\,0.66 + (6.7 + 1)\,7.64$$

$$+ (2 \times 10.4 \times 1.2)$$

$$= 32.3 + 58.8 + 25.0 = 116.1 \text{ s}$$

The RTT is little different from that calculated for the previous building. However, note that, although the values of the three terms of RTT have changed very little, the speed has increased by over three times.

For 4 cars, equation 3.8 gives an interval of:

$$\text{UPPINT} = 116.1 / 4 = 29.0 \text{ s}$$

Using equation 3.11, the 5-minute handling capacity will be:

$$\text{UPPHC} = (300 / 116.1) \times 10.4 \times 4$$

$$= 107.4 \text{ persons / 5 min}$$

However, the assumptions that rated speeds are reached in one-floor jumps are incorrect; there are also irregular floor heights. Therefore, corrections must be applied using the method described in section 3.8.6.

Height of building to H in upper zone:

To determine the height (d_H), suppose the express zone has zero distance, then:

$$d_H = 9.5 \times 3.3 + 5.0 + (6.0 - 3.3) = 39.1 \text{ m}$$

(i.e. ($H \times d_f$) plus service floor height plus floor 16 height).

Average distance between stops is given by (d_H / S), i.e:

$$39.1 / 6.7 = 5.8 \text{ m}$$

Average number of floors between stops is given by dividing the average distance between stops by the average interfloor height, i.e:

$$5.8 / 3.3 = 1.8$$

The average flight time is given by Table 3.17 by interpolation, i.e. $t_{f(1)} = 4.5$ and $t_{f(2)} = 5.7$. Therefore the average flight time is 5.5 s.

Assumed average flight time is given by $t_{f(1)}$ plus the time taken to travel 0.8 floors at 5.0 m/s, i.e:

$$4.5 + (1.8 - 1.0) \times (3.3 / 5.0) = 5.0 \text{ s}$$

Therefore the error in the average flight time is:

$$5.5 - 5.0 = 0.5 \text{ s}$$

The error in the RTT is given by the error in the average flight time times the number of stops plus 1, i.e:

$$(6.7 + 1) \times 0.5 = 3.9 \text{ s}$$

Thus the modified RTT is:

$$116.1 + 3.9 = 120.0 \text{ s}$$

This gives UPPINT = 30.0 s and UPPHC = 104.0. Thus, in this case, the error makes little difference.

3.12.6 Quick method using Table 3.11

The basic calculation is very rapid if the ready-reckoner method (i.e. Table 3.11) is used.

The input data for the original building are as follows; $N = 10$, CC $= 13$, $v = 1.6$, $d_f = 3.3$, $t_{f(1)} = 6.0$, $t_o = 0.8$, $t_c = 3.0$, $t_p = 1.2$.

It is necessary to determine a value for T using equation 3.6, i.e:

$$T = 6.0 + 0.8 + 3.0 = 9.8 \text{ s}$$

Using the Table 3.11, find $N = 10$ in left-hand column. Select the row corresponding to $v = 1.6$. Move across the columns to CC = 13 and read the RTT value, i.e. RTT = 120.9 s.

However, the calculated value of T is 9.8, not 10. Therefore, it is necessary to correct the RTT by subtracting 0.2 (i.e. 10 minus 9.8) times the correction given in the ΔT column; i.e. $0.2 \times 7.7 = 1.5$ s.

Also, $t_p = 1.2$, not 1.0, therefore add to the RTT value the t_p correction given at the foot of the column, i.e. 4.2 s.

Therefore:

$$\text{RTT} = 120.9 - 1.5 + 4.2 = 123.6 \text{ s}$$

The RTT as determined from Table 3.11 differs slightly to that obtained by the manual calculation. However, the former is the more accurate since it involves fewer rounding errors.

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4 Types of transportation system

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4 Types of transportation system

4.1 Introduction

In the past lift services have suffered from being almost an afterthought, with machine rooms located in out-of-the-way places such as under staircases. Fortunately, that practice has diminished, and lifts are now regarded as one of a building's main services for, without the correct number, type and size of lifts, commercial property can be difficult to let and rental values can suffer.

Part 5 of *BS 5655*(1) sets out the standard minimum sizes for various lift capacities. These sizes may be fine-tuned in negotiation with the lift supplier to suit the particular circumstances. However, certain safety factors are not negotiable. Safety must be ensured at all times and this applies equally to passengers and service engineers. Any alterations should not jeopardise the provision of good, safe access to equipment after installation since it will be necessary to carry out repairs to the equipment after installation. The final layout must take account of space requirements for future maintenance.

Type, speed, load and layout of the lift system all contribute to the user's perception of the service provided. Passenger cars should be elegant and features such as handrails and fans are worth considering. The design, however, must be practical from the users' point of view and push buttons and fixtures, for example, should be selected not only on the basis of appearance but also their practicality (see section 6.15).

The economic life cycle for the types of system depends upon the duty and standard of maintenance employed. Typically, a 20–25 year life span can be anticipated. During this time seals, bearings and other components subject to wear will require replacement.

4.2 Passenger lifts

4.2.1 General

The modern passenger lift appears, or should appear, to be a simple means of transport within a building. This apparent simplicity belies a complex and sophisticated mechanical, electrical and microelectronic system.

The criteria on which passengers judge the lift are those of:

— Safety: the motion of the doors should be smooth and safety devices should be provided to ensure that passengers entering or leaving the lift car will not be hurt if the doors start to close. The levelling of the car to the landing floor should not constitute a tripping hazard and should allow easy movement of trolleys and wheelchairs.

— Comfort: the ride between floors should have acceptable levels of acceleration and jerk (rate of change in acceleration) and vibration should be kept to a minimum. Quiet operation of the doors and noise levels during travel are important factors in overall passenger comfort. Noise levels on landings must also be kept to a minimum since some buildings do not have lift lobbies.

— Service: passengers regard waiting time as the appropriate measure of quality of service for a lift system. However, this is difficult to measure and quality of service is usually quantified by a theoretical interval time, related to handling capacity (see section 3).

The type of building and the potential traffic demand will determine the choice of control for the lift system. After consideration of any special client requirements or traffic patterns, the building designer should select a suitable control system (e.g. single button, down collective, full collective or group control).

Lift manufacturers and some consultants now use computer simulation programs to help designers to arrive at the correct lift scheme for the particular building. By using software models of the building, the computer can accurately simulate the transport of the passengers. The efficiency of the intended system can then be observed for all traffic situations (see also section 3).

All lift systems installed within the UK must satisfy the requirements of *BS 5655: Part 1*(2) or *Part 2*(3). These set the minimum standard to which all parties should comply and help the designer to fulfil the three basic passenger requirements of safety, comfort and service.

Lift suppliers offer ranges of products from 'pre-engineered' lifts to one-off systems tailored to individual requirements. Pre-engineered lifts offer a limited choice of options of styling and function but the production line methods used in manufacture help to reduce costs. Custom-tailored systems are appropriate to more complex situations in which a more sophisticated design is required. With custom or one-off designs, the price reflects the extra production costs and longer manufacturing and delivery times.

With the introduction of modern, versatile microprocessor-controlled lift systems it is possible to tailor lift groups to different types of buildings. However, the lift drive, door control and group control must be correctly specified to ensure that the required quality of lift service and safety is provided for the customer and the passenger.

Paternoster systems, consisting of a number of doorless cars moving continuously in a single well, are obsolete. Few systems are still operating in the UK and no new systems have been installed for many years, the relevant British Standard having been withdrawn. For these reasons, paternoster systems are not considered in this *Guide*.

4.2.2 Applications of passenger lifts

Within the UK there are five main types of buildings, each with differing requirements for passenger lifts.

4.2.2.1 Offices

The prime objective is to transport passengers quickly and efficiently to their places of work. The quality of service in terms of interval and waiting time should be high. The psychological effects of long waiting times on the work force and, more importantly, on customers are significant.

The number of lifts, car size, type, speed, type of drive, drive control and door control all affect the efficiency of the lift system.

The aesthetic aspects of the lift system, e.g. call buttons, position indicators, car interiors and the ride comfort, reflect the company's image and must harmonise with the architecture. The design must also consider passengers with special needs.

4.2.2.2 Residential buildings

Modern architectural and design concepts demand careful consideration of the needs of the passengers using the building. This is particularly true for residential buildings which should provide a pleasant and safe environment for the occupants.

A well-designed residential building ensures that its inhabitants can easily and safely move within the building. Parents with children and shopping, the elderly and especially those with special needs should be provided with convenient means of transport.

The requirement for lifts in buildings of this type is very dependent on the residents occupying the building and both the required performance and aesthetic appeal will vary between luxury apartments and local authority housing.

If the access to the lifts is not restricted, as in the case of many local authority buildings, the car fixtures and fittings should be robust in design and vandal resistant.

4.2.2.3 Hotels

The requirements of the lift system are different to those for offices, and the company or hotel image will be reflected in the quality of the lift. The major difference is likely to be in the control of the doors: 'intelligent' door controllers are needed to ensure that the doors do not close on passengers or their luggage, thereby giving the lift a softer and quieter image. Signage requirements may also differ.

4.2.2.4 Hospitals

The passenger lifts in hospitals serve two distinct functions; transportation of patients (including those being moved on beds) and transportation of the staff and general public.

This dual role is performed by the lift group controller, which allows the staff to call lifts out of normal passenger service to serve as bed lifts. The waiting time for lifts on bed service must be very short since this control mode may also be used for emergencies.

The transportation of patients requires lifts which will provide a smooth ride and, therefore, the levels of both acceleration and jerk should be kept low. The operation of the doors should allow for the slow movement of passengers into and out of the lift car. The lift door safety edges should be of the electronic (non-contact) type, as the slightest contact with an infirm or elderly patient should be avoided.

The lift groups should be able to perform efficiently during visiting times during which, depending on hospital visiting policy, the building population may double within an interval of 30 minutes.

For the general public, the car interior should have clear and concise floor and ward indication. Cars should also be designed to be easy to clean and vandal resistant.

4.2.2.5 Car parks

Of all lift types, car park lifts are subjected to greatest misuse. Unlimited public access means that vandal resistant fixtures are essential. Electronically controlled doors are recommended owing to the use of shopping trolleys.

4.2.3 Grouping of passenger lifts

The grouping of passenger lifts is particularly important if they provide the main means of vertical transportation within a building (see also section 2.4.2).

BS 5655: Part 6[4] gives recommended layouts for groups of lifts. Where a building layout cannot accommodate these arrangements the following factors should be considered:

— location of push buttons

— location and type of landing indicators

— walking distances to lift entrances in a lift lobby.

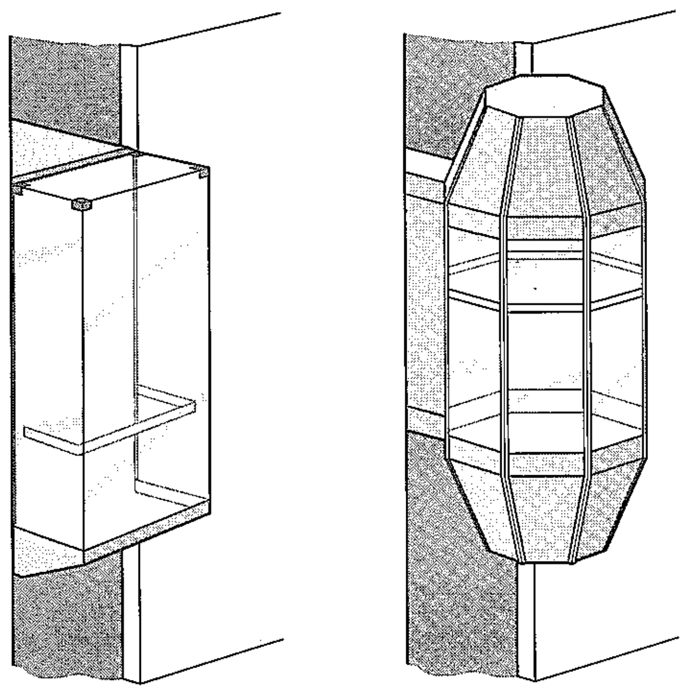
It is suggested that the position of the central lift core should be towards the centre of the building and walking distances should be no greater than 45 m from any point in the building.

4.2.4 Machine room

For hydraulic drives, the machine room is ideally located adjacent to the lift well at the lowest level served. The machine room may be located remote from the lift well, but if the distance is greater than 6 m advice should be sought from the lift supplier.

For electric traction drives, the machine room is ideally located directly above the lift well. Alternative locations adjacent to the well are possible but costly. Further guidance on machine rooms is given in section 4.

Machine room sizes are recommended in *BS 5655: Part 5*[1]. Access to the machine room must be sufficient for the passage of lift equipment. In all cases, the access door must be lockable and open outwards.



(a) (b)

Figure 4.1 Typical observation lift cars; (a) rectangular without mullions, (b) octagonal with mullions

4.3 Observation lifts

4.3.1 General

Observation lifts consist of a glass lift car, running within a glass or open-sided lift well, see Figure 4.1. They are referred to by various names including wallclimber, scenic, panoramic, glass and panorama lifts. They are often installed as an architectural feature in a building within an atrium or, occasionally, external to the building. Lifts of this type are also installed to serve a specific purpose such as to enable the inspection of some structure or assembly.

Although observation lifts of a given size have nominally the same transportation capacity as enclosed lifts, planning for these lifts requires consideration of a number of factors in addition to those discussed in section 3. The presence of observation lifts within a building may attract sightseers and 'joyriders' which will increase the overall lift requirements for the building. Also, where such lifts are to be considered as part of the building's transportation system, a lower handling capacity should be assumed since most passengers will wish to enjoy an unobstructed view through the glass panels.

Where two or more observation lifts are required to meet the likely traffic density they should be grouped at a single convenient access point. This provides both economy of installation and superior quality of service with reduced waiting times. Figure 4.2 shows some possible configurations. Observation lifts can be grouped together with

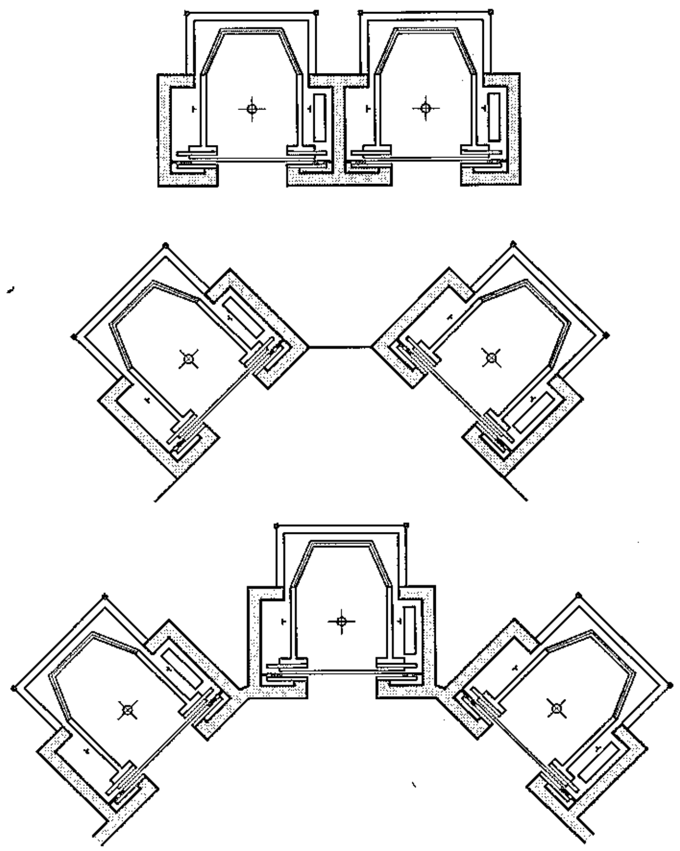


Figure 4.2 Observation lifts; some possible group layouts

ordinary passenger lifts but the two types must be clearly distinguishable to passengers before they enter the lift since some people dislike glazed lifts and are reluctant to use them.

For external lifts, careful consideration must be given to the environment in which the lifts will be required to operate and it would be wise not to rely on such lifts as the sole means of transport for the building without some form of weather shielding. Outside weather conditions can affect reliability thus rendering the whole transportation system vulnerable. Glass lifts running in glass-walled wells should be considered as an alternative to external observation lifts.

4.3.2 Drives and machine configurations

The power system chosen for any lift installation depends on required speed, likely usage and desired comfort of ride. Observation lifts can utilise all the different types of drives and configurations appropriate to passenger lifts (see section 6). However, observation lifts are often associated with prestigious installations and the quality of ride and levelling accuracy must be appropriate to the situation.

Lifts with variable speed AC or gearless drive offer sophisticated control and high standards of levelling accuracy. Acceleration and deceleration are smooth, with a fast approach to floors. Overall, a smoother and more accurate ride results from the use of a system designed for intensive service.

Hydraulic drive systems also offer smooth and comfortable ride conditions with accurate floor levelling along with the ability to incorporate a remote machine pump room. They are, however, incapable of the flight times and intensity of service achieved by electric traction drives and their travel is usually limited to a maximum of 18 m (see section 6.3).

Hydraulic drives in which the cylinder is installed in a bore hole cylinder can make an attractive architectural feature. There are no problems with hiding ropes and pulleys as with suspended lift cars and the control equipment and pump unit can be located remote from the lift. However, the 'wall climbing' illusion is lost due to the visibility of the piston.

The available headroom, lift speed and required rise are important considerations when selecting the drive system. If there is sufficient headroom to accommodate a machine or pulley room above the lift, and the rise is more than 20 m, electric traction drive would be appropriate since the required lift speed is dependent on the rise.

In situations where headroom is limited, hydraulic lifts are often more suitable although their speed and maximum rise are limited (see section 6.3). Electric traction drives using an underslung configuration (see section 6.2.5) offer an alternative solution without limitations on speed and rise.

4.3.3 Design considerations

4.3.3.1 Codes and standards

There are a number of British Standards relating to observation lifts. *BS 5655: Part 6*[4] covers general selection and installation for both internal and external applications. Glazing of the lifts and lift wells is covered in *BS 6262*[5], along with *BS 5655: Parts 1*[2] and *2*[3]. Health and Safety Executive approval should be sought when observation lifts are being considered.

4.3.3.2 Lift speed

The speed of travel is very important to the comfort of the passengers. If the rise is small, low speeds will give a leisurely journey, which enables passengers to observe the view and instills a sense of safety, while still providing good service. With higher rises, speeds need to be higher to give good service but this can only be achieved at the expense of the feeling of leisurely travel and with the possibility that people feel less secure as the walls of the building pass by.

The speed should not be greater than 1.6 m/s in situations where there is a close focal point for the passengers. Higher speeds may induce the sensation of falling off a cliff in some passengers. This causes them to stand away from the lift walls, thus reducing capacity. The intended panoramic view may also be lost.

4.3.3.3 Space requirements

Due to the unusual layout of the lift wells associated with observation lifts the space requirements are quite different to those of more conventional lifts. The counterweight and travelling cable may be required to run in a screened-off area. However, easy access for maintenance will have to be provided over the total travel. Figures 4.3 and 4.4 show the space requirements for typical traction and hydraulic observation lifts. The shape of the car may also be unusual, thereby possibly requiring a large pit area which will need to be screened-off (see section 4.3.3.4).

4.3.3.4 Screening requirements

There are a number of screening requirements particular to observation lifts[6] and both the local authority and the Health and Safety Executive should be consulted. Screens 2.5 m high are recommended where people would otherwise have access to the lift area. Screening is not required if people are unable to approach within 2 m of moving parts. Entrance screens should be 3.5 m in height.

4.3.3.5 Standard and custom designs

Most large lift manufacturers offer pre-engineered designs which, because most of the design work has already been carried out, reduce costs and delivery times. Pre-engineered designs range from a normal lift car with a glass window in the back wall and a glass-sided lift well to very

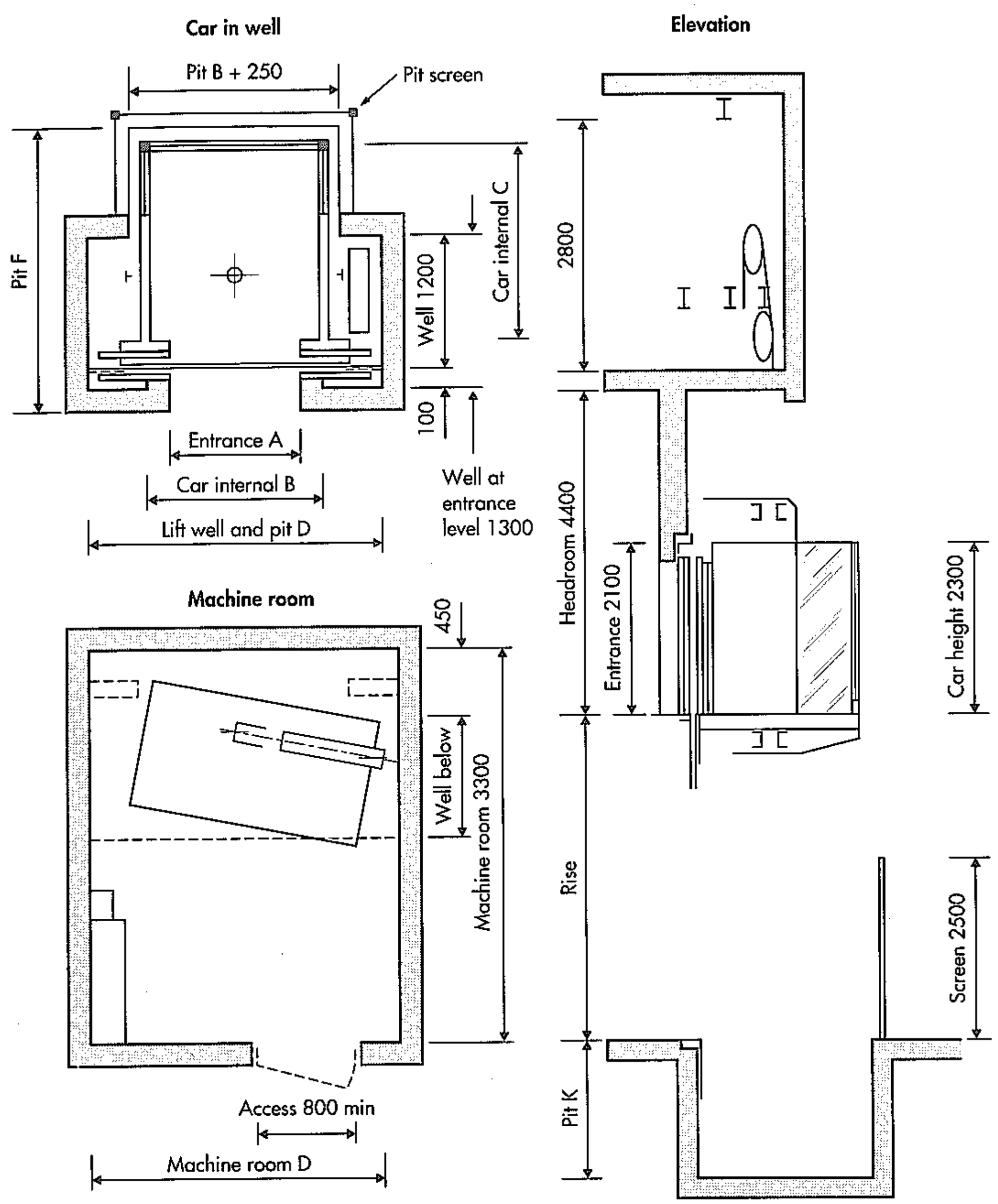


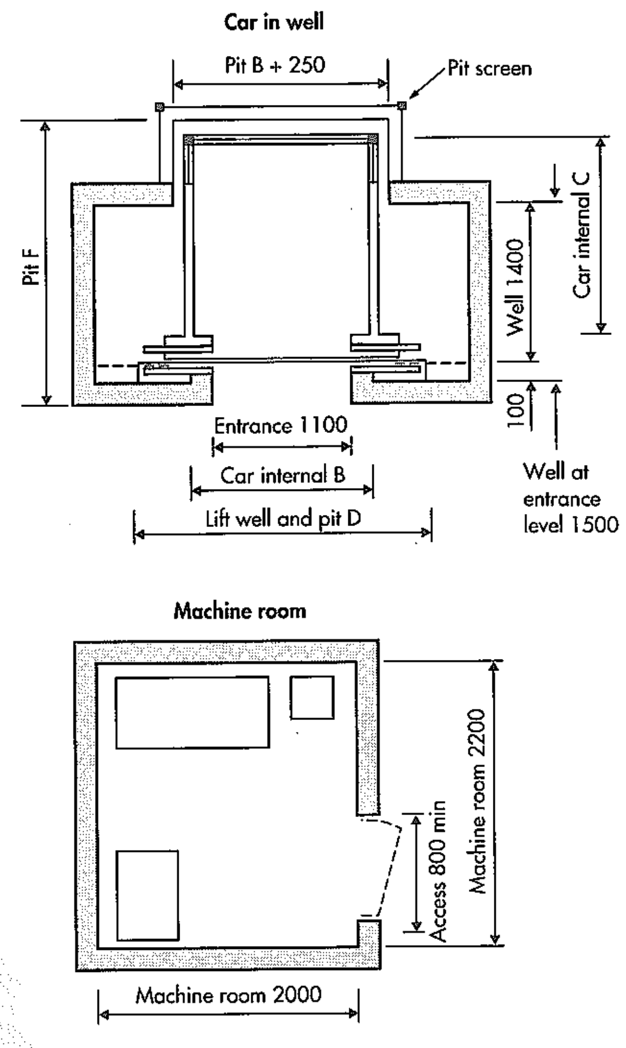
Figure 4.3 Typical space requirements for electric traction observation lift (machine above)

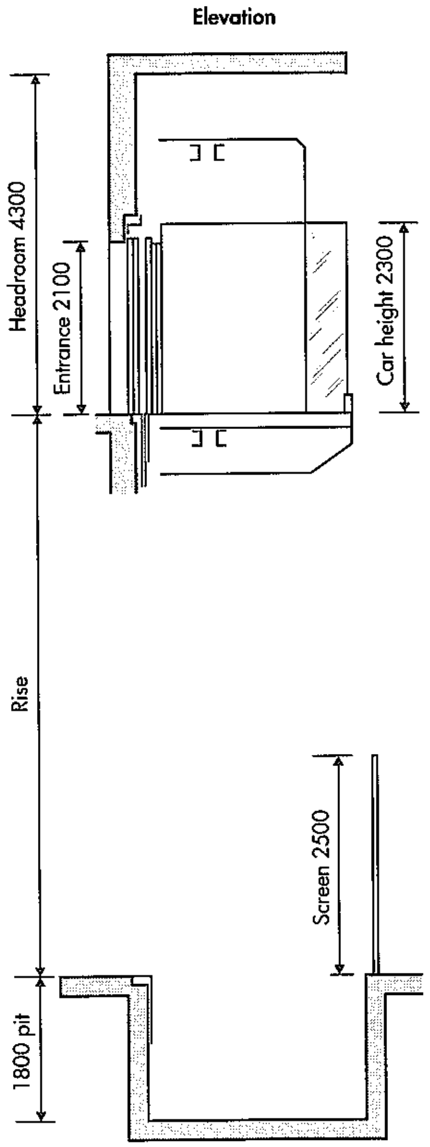
Persons	Dimensions (mm)					
	A	B	C	D	F	K
8 (630kg)	800	1100	1400	2250	1800	1900
10 (800kg)	800	1350	1400	2500	1800	2100
13 (1000kg)	1100	1400	1600	2550	2000	2100
16 (1250kg)	1100	1600	1700	2750	2100	2100
21 (1600kg)	1100	1900	1800	3100	2200	2100

sophisticated designs, such as an octagonal car with a lobby area leading into the viewing area.

Observation lifts are often tailor-made to suit the particular building in which they are to be installed. For many applications, observation lifts will need to be specially engineered because of structural problems or space limitations.

An advantage of custom-designed lifts is that they can be designed to match building decor. However, it should be noted that the time required for delivery will be greater than that for pre-engineered lifts. Special features and finishes further increase delivery times. Therefore the detailed specification must be confirmed, and the lifts ordered, as soon as possible during the planning of the building to ensure that the lift is operational by the time the building is ready for occupation.





Persons	Dimensions (mm)			
	B	C	D	F
13 (1000kg)	1400	1600	2950	2000
16 (1250kg)	1600	1700	3150	2100
21 (1600kg)	1900	1800	3450	2200

Figure 4.4 Typical space requirements for side-acting hydraulic observation lift

4.3.4 Maintenance considerations

The maintenance requirements for the machinery are generally similar to those for conventional lifts. However, door operators, rope pulleys and safety gear are often hidden by covers to enhance the appearance of observation lifts. Therefore maintenance times are increased due to the need to remove these covers to gain access to the equipment.

The glazed areas of the lift car and, for internal installations, the glass walls of the lift well must be kept clean to preserve the visual effect. Safe access must be provided for this purpose. Failure to consider this requirement at the planning stage will result in considerable problems after installation. In addition, large areas of the lift well are exposed to view, therefore further maintenance will be required to keep these areas clean.

With external observation lifts, routine maintenance and lubrication of machinery should be undertaken more frequently than with conventional lifts due to the exposure of the machinery to the elements. Care must be taken to ensure that all gutters and drains are kept clear to ensure that rainwater is diverted away from lift equipment. Suitable maintenance procedures should be introduced for any additional equipment, such as track heating, drainage and the rope guides installed to restrain the ropes in high winds. The resulting high maintenance costs mean that external lifts are generally not recommended.

It is essential that clear operating and maintenance instructions are provided due to the particular hazards associated with observation lifts.

4.4 Lifts for the aged and people with special needs

4.4.1 General

This section is concerned with lifts for public use and manufactured to *BS 5655*[4]. Different requirements apply to lifts for use in single family dwellings and *BS 5900*[7] should be consulted in these cases. Other codes and standards pertinent to lifts for general use are *BS 5810*[8] and *BS 5588: Part 8*[9]. Part M of *The Building Regulations*[10] should also be consulted.

Provision for wheelchair use will require a clear area 1500 mm by 1500 mm in front of the lift. The choice between manual or power-operated doors will depend on whether or not wheelchair users will be accompanied and whether the wheelchair needs to be able to turn around within the lift car. However, power-operated doors are usually preferred.

4.4.2 Car sizes and payload

To accommodate a wheelchair requires a five-person (400 kg) car which has a clear internal size of 900 mm wide by 1250 mm deep (see *BS 5655: Part 5*[1]). This is the minimum size suitable for use in nursing and residential homes and will accommodate an attended wheelchair but does not permit the wheelchair to be turned within the car. It should be noted that a five-person (630 kg) car 1100 mm wide by 950 mm deep (see *BS 5655: Part 5*[1]) will not accommodate a wheelchair. In all other situations an eight-person lift will accommodate an unaccompanied wheelchair.

The most popular size for such applications is an eight-person (630 kg) car with an internal size of 1100 mm wide by 1400 mm deep. Lifts of this size meet the requirements of both *BS 5810*[8] and *The Building Regulations*[10]. For larger nursing homes, a 13-person (1000 kg) lift with an internal size of 1100 mm wide by 2100 mm deep should be considered. Lifts of this size will accommodate a stretcher in addition to attended wheelchairs.

4.4.3 Car fittings and finishes

Light colours are recommended to reduce the claustrophobic effects of small lifts. Colour should be used to ensure clear demarcation between the floor of the car and the landing entrance; this is particularly important for partially sighted users.

Functional, easily cleaned surface finishes are recommended, together with a half-height mirror which creates an impression of increased car size.

A handrail along one side of the lift is essential together with large, easily operated push buttons placed at a suitable height above floor level (i.e. 900 to 1200 mm) and not less than 400 mm from the front and rear walls. In lifts with two- or three-speed doors, the handrail and push button panels should be placed on the wall adjacent to that onto which the doors close. Provision of a tip-up seat improves comfort for the elderly and infirm, as does the provision of large, illuminated controls.

Consideration should be given to providing a 'warden alarm' system in the lift car. This normally takes the form of a loudspeaker/microphone unit mounted at a low level.

4.4.4 Entrances

A minimum entrance width of 800 mm is required, with a clear entrance height of 2000 mm.

For nursing and residential homes, a swing door on the landing together with a power-operated two- or three-panel sliding door on the car is suitable for lifts for attended wheelchair use. Power-operated two-panel sliding doors on both car and landing are suitable for all lifts where unattended wheelchair use is anticipated. Suitable door contact protection must be provided, this should take the form of a non-contact device, such as a photocell or other passive detector (see section 6.8.6).

Large, easily operated illuminated push button units should be located adjacent to each landing entrance at a height of 900 to 1200 above floor level.

4.4.5 Types of drive and travel speeds

Hydraulic drive is particularly suited to lifts of this type because it provides accurate floor levelling and relevelling.

Hydraulic drive is suitable for all lifts in residential and nursing homes with a travel of up to 16 m. Recommended speeds are from 0.4 m/s to 0.6 m/s but for lifts with a travel of 12 m, a speed of 0.25 m/s is acceptable.

If electric traction drive is considered, special attention must be given to levelling accuracy. A limit of ± 5 mm is available using slow speed levelling motors.

4.4.6 Machine room

For hydraulic drives, the machine room is ideally adjacent to the lift well at the lowest level served. The machine room may be located remote from the lift well, but if the distance is greater than 6 m advice should be sought from the lift supplier.

With electric traction drive, the machine room is ideally located directly above the lift well. Alternative locations adjacent to the well are possible but costly. Further guidance on machine rooms is given in section 4.5.7. Machine room sizes are as recommended in *BS 5655: Part 5*[1].

Access to the machine room must be sufficient for the passage of lift equipment. In all cases, the access door must be lockable and open outwards.

4.5 Goods lifts

4.5.1 General

The width, depth and height of a goods lift is often a function of the nature of the goods carried and the way in which they are moved (e.g. pallets of a known size or in containers). Where possible, the designer should select one of the standardised sizes given in *BS 5655: Part 5*[(1)] since lifts manufactured to these sizes are likely to be cheaper than 'one-off' designs. However, most lift suppliers have an additional range of 'semi-standard' sizes available.

Consideration should also be given to the possibility that items other than those for which the lift is normally used may also need to be carried. For example, the goods lift may be the only means of transporting items such as office furniture and partitions between floors. Standard access doors are not always wide enough for such items.

For safe loading, goods lifts should be located in a position which provides adequate free space in front of the entrance to allow easy access. If wheeled trolleys or fork-lift trucks are to be used, adequate space to manoeuvre must be provided, with clear access to the loading area. Consideration must also be given to the cills and car flooring.

4.5.2 Car sizes and payloads

If possible, determine the specific type of goods to be moved, the overall dimensions and the weight. This enables the designer to calculate the volume and total weight expected to be moved at one time. Additional space must be allowed for any personnel who may be required to accompany the goods.

The recommended minimum internal width for cars is the overall width of the goods plus 600 mm. This allows goods to be stacked to one side while leaving an area for accompanying personnel. In the case of 'through cars', which have gates on both sides, this space is essential because the attendant will often have to unload the lift through the opposite gate and therefore requires access to the gates on both sides of the car.

When considering through cars fitted with folding shutter-type gates, it is important to check that the distance between the bunched leaves of the gate is adequate. Otherwise goods against the closed gate may encroach on the area required by the leaves of that gate when open.

Having determined the minimum size, the next largest standard size, as given in *BS 5655: Part 5*[(1)], should be selected wherever possible.

When loading is to be carried out by fork-lift trucks or other vehicles, the carrying capacity of the lift must reflect the additional load imposed by the weight of any vehicle which may enter the lift car. This does not necessarily require an increase in the size of the car, but consideration must be given to whether trucking cills will be required to accommodate the localised high loads imposed by the vehicle wheels. It may also be necessary to consider additional stiffening for the car floor at the design stage.

4.5.3 Car fittings and finishes

Good lifts should be rugged and the finishes should be easy to clean and repair. Walls and roofs should be constructed in sections to allow easy replacement if damaged. Many materials and finishes are available but the most common are either steel with a cellulose coating or a patterned stainless steel. While the latter is initially more expensive, its appearance is superior and it does not require maintenance after installation.

For very light duty, laminate-faced panels may be used. The appearance is good but the surface is more prone to damage than steel panels.

In all cases it is desirable to fit some form of bumper rail to provide a measure of protection for the walls. The rail should be mounted at a suitable height to absorb the impact of trolleys, loading pallets etc. Alternatively, a series of rails may be provided, spaced 100 mm apart up to a height of 1 m. However, bumper rails reduce the interior dimensions and this must be taken into account when calculating the required car size.

The flooring should be replaceable. Most goods lifts will have floors of patterned steel but, for light duty applications, surfaces such as aluminium treadplate or vinyl may be preferred. In applications where corrosive fluids are carried, epoxy resin or terrazzo flooring may be required. Consideration must also be given to the consequences of washing-out or hosing-down the lift car.

4.5.4 Entrances

Door configurations are dealt with in detail in section 6.8. Manual doors are specified for some goods lifts. These should be arranged to give an opening equal to the full width of the car for maximum flexibility. Folding shutter gates are usually preferred since they require a minimum of well space and are easily adapted to suit varying entrance widths. The standardised heights of 2000 mm or 2300 mm should be selected wherever possible.

Power-operated shutter gates are not recommended. If there is a specific requirement for power operation, an alternative door arrangement should be selected, such as sliding doors or vertical bi-parting doors. In these circumstances, the lift supplier must be consulted to determine the additional space requirements within the lift well.

For dual purpose lifts intended for both passenger and goods service horizontal power-operated doors are usually required.

4.5.5 Types of drive

For conventional goods lifts, both hydraulic and electric traction drive are suitable (see sections 6.2 and 6.3). Each has its own advantages and the final choice is likely to be determined by the specific application. Both types of drive require a 4-wire electrical supply of 415 volts, 3 phase, 50 Hz.

4.5.5.1 Electric traction drive

Electric traction drives are suitable for goods lifts of any capacity, and there are no travel or speed limitations. Accurate levelling can be achieved with both DC and variable speed AC drives.

Both types of drive can provide relevelling to an accuracy of ± 6 mm. Variable speed AC drives are 'direct-to-floor' drives and do not normally provide relevelling; however, floor level accuracy on arrival should be ± 5 mm.

The limitations of electric traction drives are mainly concerned with the location of machine room, available headroom and the possibility of high loads being applied to the building structure.

4.5.5.2 Hydraulic drive

Up to 1250 kg capacity, most hydraulic drives use a single side-acting cylinder unit supporting a cantilever car. This imposes a horizontal load to the supporting wall which must be considered during building design. Above 1250 kg capacity, the most common configuration is twin jacks, located with one each side of the car. This reduces the horizontal loading to a minimum.

Goods lifts do not depend on travel speed for quality of service since loading and unloading consume the greatest time on round trips. Therefore, the speed limitations of hydraulic drives are not important for goods applications. However, they are impracticable for rises greater than about 12 m or speeds greater than 0.63 m/s.

Automatic levelling to within approximately ± 5 mm is available with most hydraulic drives.

Starting currents are higher than those for electric traction lifts which may be significant if the capacity of the mains supply to the building is limited.

4.5.6 Well dimensions and construction

For initial layout purposes, the following dimensions may be used but the lift supplier must be consulted before the building design is finalised.

For hydraulic lifts with folding shutter doors:

- capacities up to 1000 kg: car width plus 600 mm, car depth plus 300 mm
- capacities over 1000 kg: car width plus 900 mm, car depth plus 300 mm

For electric traction lifts with folding shutter doors:

- capacities up to 1000 kg: car width plus 700 mm, car depth plus 300 mm
- capacities over 1000 kg: car width plus 800 mm, car depth plus 300 mm

With electric traction lifts, the load determines the size of the counterweight and for capacities in excess of 2000 kg this may affect the well width, depending on the configuration of the installation. If power-operated doors are required, the lift supplier should be consulted since this may affect the required well dimensions.

The construction of the well must be such that it will be strong enough to accept the loads applied by the lift. This is particularly important where loading and unloading is to be carried out by fork-lift trucks or trolleys.

In these circumstances, large additional loads are temporarily applied to the stationary lift. This generates a turning moment with resulting reactions on the car guides. These loads are transferred to the building structure by the guide rail fixings and the structure must be strong enough to accept these loads without degradation. While blockwork has high compressive strength, it is not suitable for expanding bolts or other heavy duty fixings. If necessary, steel or reinforced concrete sections should be used. At the very least, local areas of cast concrete blocks, suitably tied and bonded to the wall panel, should be used. However, it must be noted that lift installers cannot accept responsibility for the design of the building or its structural strength.

4.5.6.1 Well headroom

For hydraulic lifts, the recommended headroom is 3500 mm. This will normally leave adequate space for a lifting beam and retain clearances as required in *BS 5655: Part 2*[(3)].

Electric traction lifts of a similar speed and configuration require a headroom of between 3800 and 4000 mm. If vertical bi-parting doors (see section 6.9.8) are fitted to the car, additional headroom will be required, depending on the particular design.

4.5.6.2 Pit depth

For hydraulic lifts with speeds of 0.63 m/s or less, a nominal pit depth of 1200 mm is adequate when shutter gates are fitted. Electric traction lifts require a minimum pit depth of between 1300 and 1400 mm. This is less than that recommended in *BS 5655: Part 5*[(1)] but sufficient to provide safety clearances.

If vertical bi-parting doors are fitted at landings, these dimensions may need to be increased. In these cases the lift supplier should be consulted to determine the exact requirements.

4.5.7 Machine room

For electric traction lifts, the size of the machine room should be in accordance with *BS 5655: Part 5*[1] wherever possible. Specialist advice should be sought if smaller machine rooms are contemplated. Depending on machine size, machine room heights between 2400 and 2700 mm will be required. In all cases a suitable lifting beam should be installed overhead to provide lifting capability from the trap door to the approximate position of the machine.

For electric traction drives, the machine room is ideally located immediately over the lift well (see section 6.2.5). Bottom or side drives are sometimes used, but these configurations are less efficient and result in increased installation and maintenance costs.

With bottom drive, an overhead pulley room is required which should be the plan size of the lift well with a minimum internal height of 1500 mm. This may be reduced if an underslung-car arrangement is employed, see section 6.14.1. Basement machine rooms must be adjacent to the lift well with a plan size to suit the equipment and provide an adequate safe working area for maintenance. In such installations, the designer should refer to the lift supplier for guidance.

Hydraulic lifts normally require a minimum machine room size of 1800 mm by 1800 mm and 2150 mm high. This is usually adequate except for very large capacity lifts requiring more than one tank unit.

For hydraulic drives, the machine room is ideally located adjacent to the lift at the bottom level. However, if necessary the machine room can be located away from the well but the distance between the machine and the hydraulic jack should not be greater than 6 metres. In these circumstances, the lift supplier should be consulted.

All machine rooms should be heated and ventilated to control the temperature (see section 9).

Access to machine rooms for hydraulic lifts and bottom drive electric traction lifts must be sufficient for the passage of lift equipment. For electric traction lifts with overhead machine rooms, a personnel access door should be provided in addition to the trap door. In all installations, access doors must be lockable and open outwards.

4.6 Service lifts

4.6.1 General

Service lifts are intended for carrying goods only and their dimensions and designs are such that they are unsuitable for carrying persons. Lifts conforming to *BS 5655: Part 3*[11] should be specified to ensure reliability and safety in operation.

When deciding on the size of car and its entrance, it is important to take into account the need for clear access for loading and unloading. The size of packaging and transportation containers must be considered as well as handling clearances.

4.6.2 Car sizes and payloads

Most manufacturers offer a range of standard car sizes, normally in 100 mm increments, based on *BS 5655: Part 3*[11], which relates the rated load to a maximum car floor area, see Table 4.1. Either the internal width or the depth of the car is limited to a maximum of 1400 mm, the other dimension being determined to comply with the maximum permitted floor area appropriate to the rated load.

The rated load is generally limited to a maximum of 500 kg. Car heights, or compartments with a fixed shelf, are also restricted to 1400 mm.

Lift car dimensions must be appropriate for the size of the goods to be carried. Any containers to be used should be taken into account since these could affect the rated load.

Table 4.1 BS 5655 recommendations for sizing of service lifts

Rated load (kg)	Maximum floor area (m^2)
10	0.15
50	0.50
100	0.75
200	1.00
250	1.25
500	1.25

Automatic loading/unloading systems are available which employ power-operated rollers in the car with non-powered rollers on the landings. For carrying items such as documents, the car may be fitted with tilting trays and collection boxes at each landing. In both cases power-operated entrances are required.

Side runners can be provided within the car to support serving trays etc. These remain permanently in place, and would need to be specified to suit a given size of tray. Alternatively, removable frame systems, custom made to requirements, can be provided.

For transporting food, heating panels can be fitted within the car. In this application, solid protection for car entrances is required and it is also advisable to specify smooth edges and corners within the car to enable easy cleaning.

4.6.3 Entrances

For cars with adjacent (i.e. front and side) entrances, the width of the side entrance is normally less than that for the front entrance. When selecting such cars it is imperative to ensure that items loaded through the front entrance will be able to be unloaded from the side entrance.

For service lifts with rated loads of 250 kg and above, car entrances should be protected by means of doors or gates. For lifts with through (i.e. front and rear) or adjacent entrances, car entrance protection is required for all rated loads. Where car entrance protection is provided, the clear entrance width is normally less than the full width of the lift car and this must be taken into account to ensure easy loading and unloading of the car.

Floor level or counter-height entrances can be provided, depending on the nature of the items being transported. Entrance doors or gates may be either manual or power-operated.

4.6.3.1 Manual entrances

Manual vertical operating shutters (bi-parting or 'rise and fall') are normally fitted at serving height on landings and may also be fitted to the car. Hinged doors for landings are sometimes provided at floor level as an alternative.

Open collapsible gates or roller shutters may be provided for car entrance protection. Drop-bar or similar protection for cars is also available to ensure that goods are restrained during travel, but these methods are suitable only for service lifts which carry bulky items or containers.

4.6.3.2 Power-operated entrances

Power-operated vertical shutters or automatic closing hinged doors may be provided. Full power operation for hinged doors can be provided but this is expensive and normally a self-closing mechanism is adequate.

4.6.4 Types of drive

Service lifts normally employ an electric traction drive, using either a drum, sprocket or counterweight arrangement. The ideal position is directly above the well. Bottom or side drive will result in a more costly and less efficient installation. The latter also requires a separate machine room enclosure. Travel speeds are usually between 0.2 and 0.5 m/s but, for longer travel, speeds may be as high as 1 m/s.

4.6.5 Well dimensions

Most service lifts are supplied with their own structural frames to minimise builder's work.

For initial layout purposes, the following well dimensions can be used:

- well width: car width plus 500 mm
- well depth: car depth plus 300 mm.

The actual overall sizes will be confirmed by the lift supplier who will take into account the lift arrangement and entrance details.

4.6.5.1 Well headroom

The height of the soffit of the well (i.e. under pulley or machine room floor) above floor level of the highest floor served should be the height of the serving hatch plus the car height plus an allowance of between 500 and 1000 mm.

4.6.5.2 Pit depth

For floor level service, a pit of depth 150 to 1000 mm is required, depending on car design and landing door arrangements. A pit is also required if the height of the serving hatch is such that there is insufficient height below the hatch to accommodate the landing shutters.

4.6.6 Machine room

For electric traction lifts with machine room above, a minimum of height of 600 mm is required for the machine room. The plan dimensions should be the same as those of the lift well below. In some instances a separate area will be required to accommodate a control panel if this cannot be accommodated within the machine room itself.

For electric traction lifts with machine room adjacent or below, the pulley room above the well should be to the same plan area as the well and a height of between 200 and 500 mm.

The machine room can be positioned to either side of the well or within the well, directly below the serving height of the lowest floor.

Items of equipment will need to be moved into and out of the machine room for installation, replacement and repair. A minimum access opening of 600 mm by 600 mm is normally recommended but the final size depends on the equipment contained in the machine room. The area in front of the access door must be clear of ducting, piping, ceiling panels etc.

4.7 Motor vehicle lifts

4.7.1 General

The most common application for motor vehicle lifts is to gain access to restricted garage parking associated with office or residential accommodation. When considering this type of lift, it is important to allow adequate space for turning from the road and for manoeuvring within the garage area. Provision must be made for the removal of fumes from the lift car and well, in addition to their removal from the garage area itself.

It is unlikely that any supplier will be able to offer a suitable standard design and therefore consideration of the likely delivery time will be particularly important.

4.7.2 Car sizes and payloads

Unless small cars only are expected to be carried, the lift car dimensions should be adequate to carry all standard production models, including the largest Rolls Royce. The lift car should be large enough to allow for driver errors in alignment and provide room to allow the driver to leave the vehicle in an emergency.

The recommended internal dimensions are:

- width: motor vehicle width plus 750 mm
- depth: motor vehicle length plus 500 mm

For a lift to carry all types of cars, the minimum size recommended is 2700 mm wide by 6200 mm deep subject to checking the current dimensions of the largest models to be carried.

A lift car height of 2000 mm is satisfactory for most applications but a height of 2100 mm should be allowed if the lift is likely to carry vehicles fitted with roof racks.

4.7.3 Entrances

The entrance does not need to be the full width of the lift car, but must be large enough for easy access including sufficient clearance for wing mirrors, roof racks etc. Entrances, particularly in basement areas, will usually require to be fire rated and it is important to advise the lift supplier accordingly.

If the entrance is exposed, consideration must be given to weather-proofing the equipment, including control stations and doors. Ramps should be provided in front of such entrances to prevent rainwater from entering the lift well.

4.7.3.1 Manual entrance doors

The simplest form of entrance doors are folding leaf shutters. They are inexpensive, reliable and take up minimum well space but are not recommended because they are often unacceptable to users. The leaves intrude into the lift car and it may be necessary to increase the internal length accordingly. Folding leaf shutters require the driver to leave the vehicle on three occasions and therefore may not be suitable for all applications.

4.7.3.2 Power-operated entrance doors

Four-panel centre-opening doors provide a reliable and relatively inexpensive system. However, these doors require considerable well space. Vertical door systems take up little well space, but are more expensive and are less reliable. Vertical doors should be operated by continuous pressure control buttons.

Where automatic power-operated entrances are used, it is important to provide additional door closing protection to both the landing and the car entrances to ensure the doors cannot close on the vehicle. This protection normally takes the form of a light beam in the landing architrave and car side wall (or front return where fitted).

4.7.4 Types of drive and travel speeds

For travels up to four floors (i.e. approximately 12 m) twin-ram hydraulic systems, with speeds in the range 0.2 m/s to 0.3 m/s, are the most suitable. A direct-acting central piston provides an economic solution where groundworks permit the required borehole. However, the cost savings resulting from the simpler system will be offset by the additional costs of providing the borehole.

Travels in excess of 12 m are better served by electric traction drives with speeds up to 0.5 m/s. The ideal drive position is directly above the well. In view of the high payloads it is common to use rope factors up to 4:1 to reduce the load on the drive. Floor levelling is an important consideration and should be in the order of ± 20 mm.

Control stations should be positioned to be within easy reach of the vehicle driver. Strip-type pushes, fitted to both sides of the lift car, will permit operation from within the vehicle.

4.7.5 Well dimensions

For initial layout purposes (for lift cars with front and rear entrances) the following dimensions may be used for both hydraulic and electric traction motor vehicle lifts:

For lifts with manual folding leaf doors:

- well width: lift car width plus 900 mm
- well depth: lift car depth plus 600 mm.

For lifts with power-operated vertical doors:

- well width: lift car width plus 900 mm
- well depth: lift car depth plus 500 mm.

For lifts with power-operated four-panel centre opening doors:

- well width: lift car width plus 900 mm (minimum of 3600 mm with 2200 mm wide doors, add 150 mm to well for every extra 100 mm in door width)
- well depth: lift car depth plus 800 mm.

Note that electric traction lifts with motor below and without a pulley room require the above well widths to be increased by 500 mm.

4.7.5.1 Well headroom

For a lift car height of 2000 mm, the height of the soffit of the well (i.e. under pulley or machine room floor) should be 4100 mm. The headroom should be increased by 100 mm for each additional 100 mm of car height.

4.7.5.2 Pit depth

Typical pit depth is 1800 mm.

4.7.6 Machine room

For hydraulic lifts, the room should be adjacent to the lift well at lowest level served and should be at least 2000 mm by 2000 mm with a clear height of at least 2150 mm.

For electric traction lifts with overhead machine room, the room should have the same plan dimensions as the well but with an extension of 500 mm to one side. A trap door for access to the motor room should be provided. The minimum size of the trap door, which may be located above the well, should be 1500 mm by 2000 mm.

For electric traction lifts where the machine room is below but with an overhead pulley room, the pulley room should have the same plan dimensions as the well, with a minimum height of 1500 mm. The machine room should be adjacent to the well at lowest floor served, but may be positioned to either side of the well. It should be 2500 mm wide and the same depth as the well (i.e. 2500 mm by 7000 mm).

Large items of equipment will require to be moved into and out of the machine room for installation, replacement and repair. Therefore doors, access traps and lifting points must be provided to suit the individual building design. Access openings should be at least 2000 mm by 1500 mm.

Means should be provided to control the machine room temperature (see section 9).

4.8 Rack and pinion lifts

4.8.1 General

While the use of rack and pinion drive may seem to be a comparatively recent development, it has been applied to the vertical transportation of passengers and goods in the construction and mining industries since about 1960. The ease of initial erection and subsequent extension as building work progresses has led to the rack and pinion lift replacing the rope hoist for passenger transportation on building sites in the UK.

4.8.2 Applications

The main applications for rack and pinion lifts are in factories, warehouses and retail buildings where general purpose passenger, goods and heavy duty goods lifts are required (as defined in *BS 5655: Part 6*[31]).

Special applications include:

- TV and radio masts
- chimneys
- cranes
- grain silos
- offshore exploration/production platforms.

The car is cantilevered from a guide mast, so making possible applications where building support can be offered from one side of the lift only, as with some types of observation lift and installations without a well.

4.8.3 Drive system and safety gear

The basic components of a rack and pinion drive are a continuous length of machine-cut toothed bar (rack) and a pinion or pinions which are held in permanent mesh with the rack (see Figures 4.5 and 4.6). The pinions are driven by individual motors (usually electric but may be hydraulic, petrol or diesel) via reduction gearing. In order to simplify the range of components and to maintain constant motor and pinion sizes, high payload require-

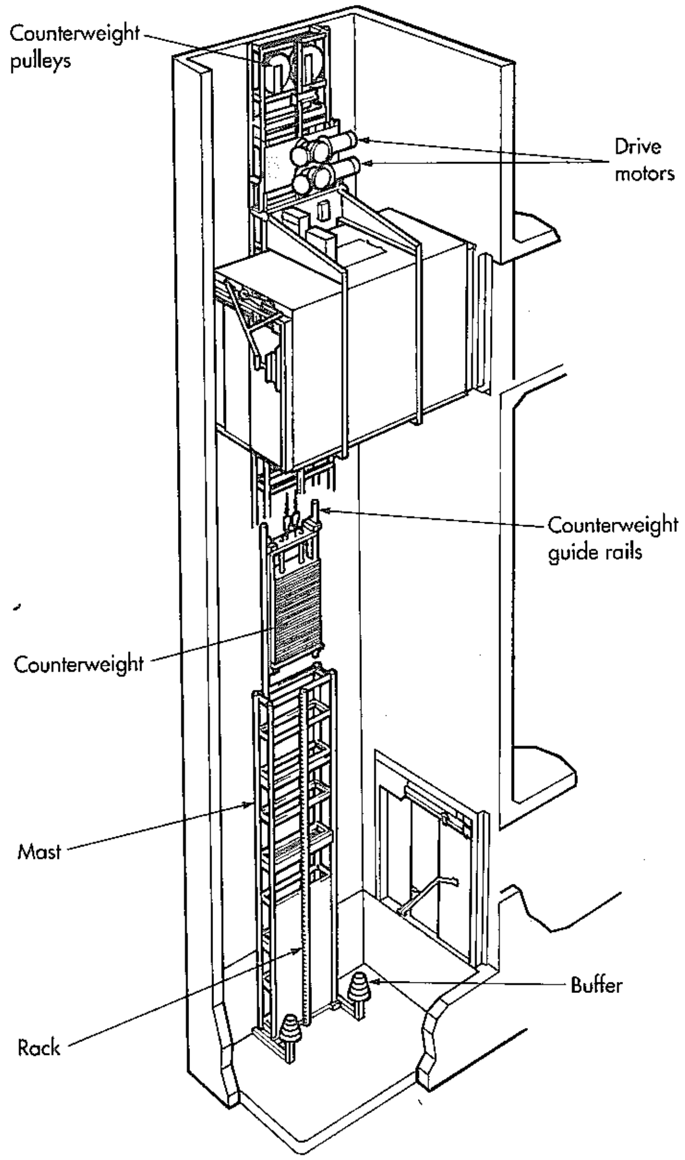


Figure 4.5 Rack and pinion lift — general arrangement

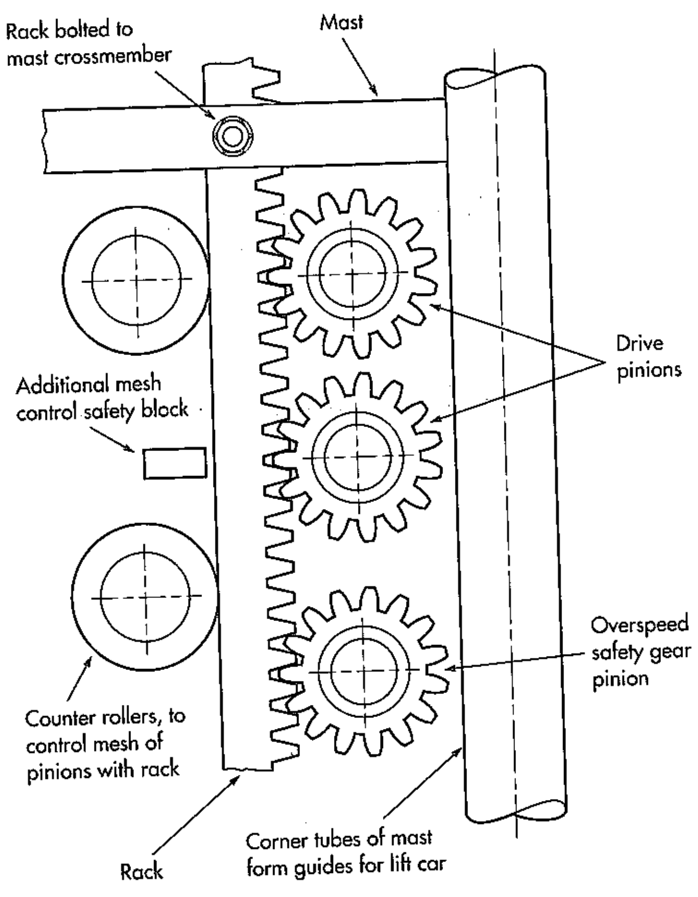


Figure 4.6 Detail of rack and pinion mechanism

ments are often met by using one, two or three drive units, each unit having an identical motor gear box and pinion. The drive units are usually mounted on the lift frame, above the car.

The rack is bolted to a rigid mast section, the rack and the mast normally being produced in standard 1.5 m lengths. These are bolted together to give the required lifting height. The mast forms the guide rails and also provides the structural support for the complete lift. The corner tubes of the mast are enclosed by the guide rollers and the car is thus cantilevered from the mast and restrained to follow the path set by the mast.

At various intervals, generally between 3 m and 12 m, the mast is laterally restrained by ties to the building. These ties can be adjusted to accommodate discrepancies in mast verticality.

The car, which is fitted into the sling, is of similar construction to those found in electric traction or hydraulic lifts. Similarly, the car and landing doors usually conform to normal practice. The lift is usually counterweighted, the weights being guided within the mast, and all vertical forces are transmitted directly to the foundation. The pulleys associated with the counterweight are mounted in the top mast section.

The safety gear will normally be of the type used on construction hoists for over 20 years. Construction hoist applications have always required regular drop tests[12] to prove the safety gear under loaded and mobile conditions, at least every three months. Therefore, such lifts are designed to enable quick and easy proving of the safety gear, without damage to components

The overspeed safety gear is normally mounted on the car sling and acts directly between the car and rack giving immediate response to overspeed. There is neither a governor rope nor any well-mounted equipment. The overspeed governor and arrester gear are usually contained within a sealed enclosure and act as a single system. The overspeed governor is directly driven at car speed by a steel pinion in permanent mesh with the mast rack. The arrester gear applies braking torque to the same pinion and brings the lift to a halt with all the arresting forces being absorbed through the rack. Braking is very progressive and typical braking distances are about 1 m from the point of tripping.

4.8.4 Dimensions, payloads and travel distances

The load rating of the lift is dependent upon the car size as defined in *BS 5655: Part 1*[2]. The range of rated loads, speeds and car sizes is as given in *BS 5655: Part 5*[1]. Smaller cars, for loads down to 200 kg, are available for special applications.

Car doors, landing doors, well and pit dimensions are all to the appropriate parts of *BS 5655*. Doors may be manually or power-operated.

Travel distances are largely unlimited; the tallest installation at the time of publication is 640 m.

4.8.5 Lift speed and controls

Lift speeds are according to those advised in *BS 5655: Part 5*[1], with single speed and variable speeds being available. The maximum lift speed for rack and pinion drive is 1.5 m/s.

Floor call systems, alarms, telephones, car-top control and landing levelling accuracy are all as for normal lift practice and as quoted in *BS 5655*.

4.8.6 Special features

There is no requirement for a machine/pump room and the well is not required to support the vertical loads and forces associated with the lift. All vertical loads from the lift are transferred via the rack to the mast. Rack and pinion lifts are particularly suited to situations where the lift is installed without a well, as with lifts exterior to a building. There is no requirement for the erection of accurately plumbed and parallel guide rails.

The height of travel can be increased or decreased by the addition or removal of mast sections. Relocation of the lift, as may be required when reorganising a factory, is also readily achieved. By jacking-up the mast, sections may be inserted into or removed from the base of the installation if there is any change in the level of the lowest landing served.

Due to the ease of erection of the mast from the car roof (a practice developed over many years of experience with construction hoists) there is no need for a scaffold to be erected in the well during installation of the lift.

The guide rails may be preformed so that the lift can follow a varying radius of curvature, as may be found in offshore platform support legs, cooling towers, etc., the car being restrained to remain vertical.

4.9 Scissor lifts

4.9.1 General

Scissor lifts provide a simple, robust and low-cost means of lifting loads through short distances. While geometrically inefficient, the lifting mechanism is all contained within the dimensions of the baseframe thereby providing a very compact lifting device. Lifting capacities range from a few kilograms to tens of thousands of kilograms and most scissor lifts are bespoke designs manufactured to suit the particular requirements of the specifier. A typical scissor lift is shown in Figure 4.7.

Scissor lifts are manufactured in accordance with *BS 5323*[13]. Fixed or mobile types are available and typical applications include:

- lorry loading/unloading
- feeding materials to machines
- transferring of materials/equipment
- access lifts for the elderly and people with special needs.

4.9.2 Configuration

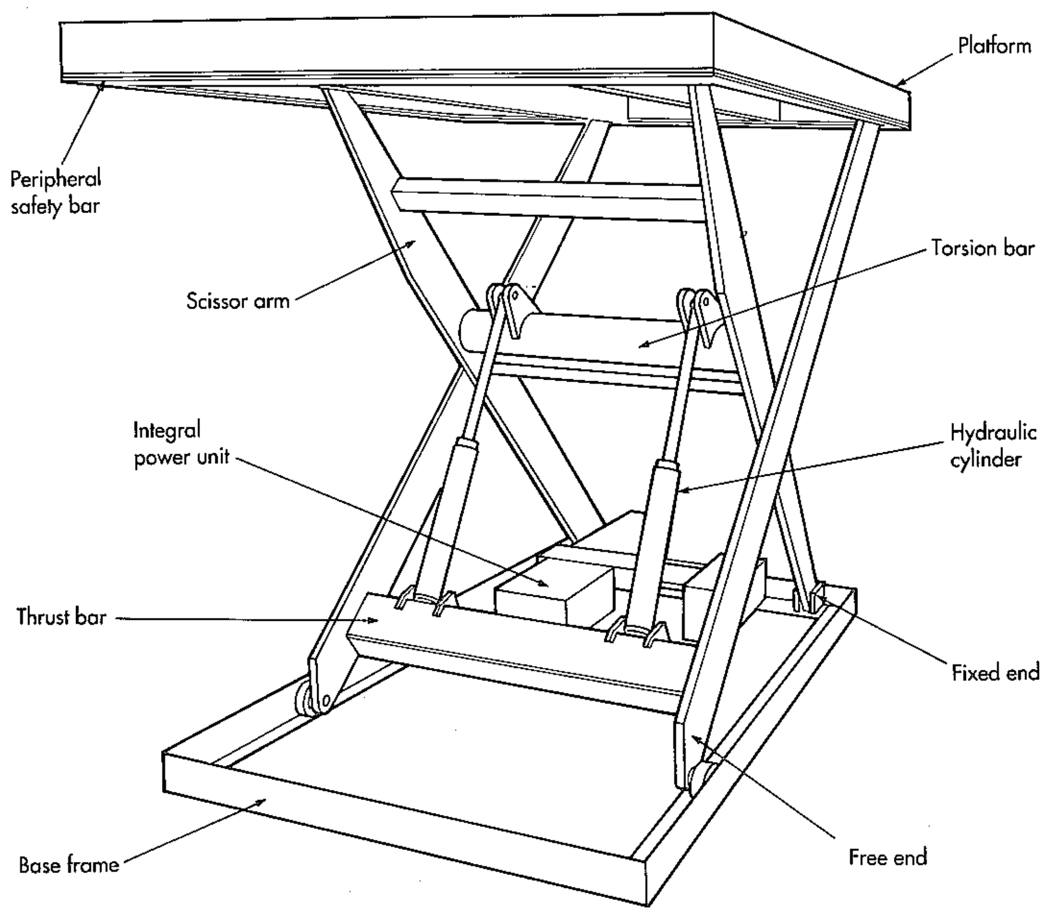
When positioning, consideration should be given to the configuration of the lift to ensure stability. Scissor lifts are most stable when they are loaded over the platform and the load being applied is parallel to the plane of the scissor legs.

All scissor lifts have a closed height and this may obstruct access onto the lift table or cause an obstruction. In such cases a pit will be necessary, the depth being determined by the closed height of the lift. External pits should be provided with suitable drainage.

4.9.3 Dimensions, payloads and travel distances

The load rating depends upon manufacture, but can be to 30 000 kg. The rise varies according to the scissor arrangement to a maximum of 3000 mm.

Figure 4.7 Typical scissor lift



The platform length is dependent upon the vertical travel dimension because the scissor arms are accommodated beneath the platform when in the closed position.

4.9.4 Power system and control

The power system usually consists of an electric pump, hydraulic fluid reservoir and control unit. This is most frequently accommodated beneath the platform, but may need to be remote from the machine.

Controls can be fixed or hand-held. The maximum voltage for fixed controls is 240 volts and 110 volts for hand-held controls.

4.9.5 Safety devices

Most scissor lifts will have a safety trip-bar to arrest downward travel in the event of an obstruction. Consideration should be given to guarding the underside of the lift to prevent the trapping of people and objects.

In public places, e.g. a loading bay, barrier protection must be provided to the underside of the scissor lift to prevent access. *BS 5323*[13] gives recommendations on guarding requirements.

Safety of the load on the platform can be provided by handrails, interlocking platform and landing gates, wheel stops, loading flaps, etc.

The local environmental health officer should be consulted to determine the precise safety requirements in a particular area.

4.10 Escalators and passenger conveyors

4.10.1 General

Escalators have been in public use since the turn of the century and their derivative, the pallet passenger conveyor, since the 1950s.

BS 5656[14] describes these devices as follows:

- Escalator: a power driven installation with endless moving stairway for the conveyance of passengers in the upward or downward direction.
- Passenger conveyor: a power driven installation with endless moving walkway (e.g. pallets, belts etc.) for the conveyance of passengers either on the same or between different traffic levels.

The safety and operating requirements for both escalators and passenger conveyors are covered in *BS 5656*[14] and Health and Safety Executive Guidance Notes *PM 34*[15] and *PM 45*[16].

The design of escalators and passenger conveyors falls into three distinct categories, depending on the application.

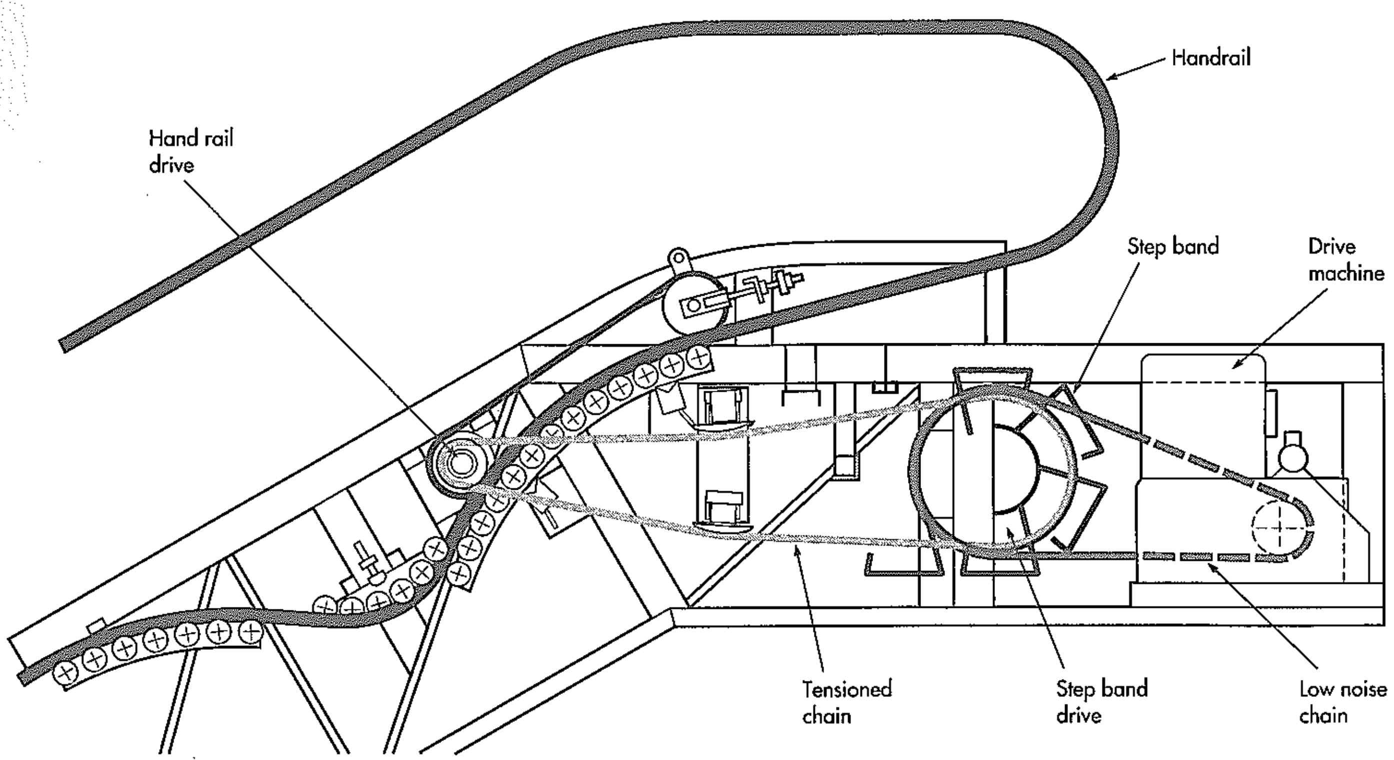


Figure 4.8 Drive arrangement for typical escalator

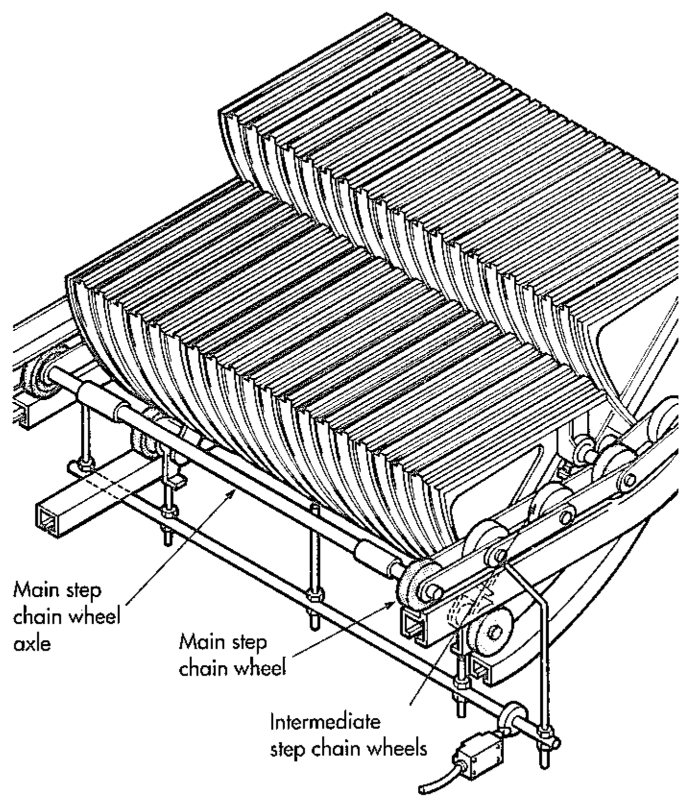


Figure 4.9 Detail of step chain

The differences in cost between the three categories are considerable and care must be taken in assessing the need. Escalator capacities, speeds and configurations are considered in section 2.

The three basic applications are:

(*a*) Commercial: i.e. 'normal' commercial usage in department stores, offices, medium airports etc.

(*b*) Transportation: i.e. airport terminals, railway stations, bus stations etc.

(*c*) Mass transit: i.e. high density transport systems such as the London Underground.

With few exceptions, escalators are installed for use by the general public of all ages. Therefore, great care must be taken to ensure compliance with all the safety and operating requirements given in references 14, 15 and 16. Particular requirements for 'public service' applications, i.e. (*b*) and (*c*) above, are given in *BS 5656*[14].

Escalators offer considerable scope to the designer by the imaginative use of glass, cladding and polished metal finishes. Careful design of the lighting may also enhance the appearance. However, consideration must also be given to the following:

- Coloured handrails require regular cleaning, using special materials, at least every two weeks if the appearance is to be preserved. Black handrails are less attractive but more practicable for public usage.
- Where glass balustrades are installed close to a wall, rubbish will collect in the space between the wall and the balustrade. This will be difficult and expensive to remove.
- Stainless steel does not suffer damage by scratching from shoes, luggage etc. and is therefore an appropriate material for high density applications.
- In some recent designs, the moving equipment is observable through glass cladding. This is very effective when the escalator is lit internally but the difficulties of cleaning the glass must be considered. The manufacturer should determine how this is to be accomplished and should recommend a frequency, based on experience. This will form part of the regular maintenance procedure but will need to be identified as a specific item.

4.10.2 Layout and principal components

The principal components of a typical escalator are shown in Figure 4.8. In this example, the drive machine is situated outside of the step band to allow ease of maintenance. Power transmission from the machine to the main drive of the step band is via a shock absorbing low-noise duplex chain. The handrail is driven from the main drive via an automatically tensioned chain. The handrail drive is designed to ensure synchronous handrail and step band speeds.

The main components of the step chain are illustrated in Figure 4.9. Each step is located by an axle. The intermediate wheels ensure that the load is distributed evenly around the track system.

4.10.3 Safety aspects

When inviting tenders for escalators it is essential to confirm with the manufacturer that the following are included:

- All equipment conforms to the requirements of the relevant codes of practice.
- The cost of brush guards is included to comply with the requirements of the Health and Safety Executive[15].
- Maintenance costs include for annual cleaning, as a fire precaution, and annual inspection as required by HSE Guidance Note *PM 34*[15] (see also section 12).

It is recommended that the step band should be able to be moved manually when power is not available e.g. during periods of 'caretaker' maintenance. This may be accomplished by the provision of hand-winding devices on the motor and a release mechanism on the brake.

When fire protection systems, such as smoke detectors and sprinklers, and shutters are required by the relevant fire authority the manufacturer should be instructed to include such equipment and necessary interfaces.

Pipework and necessary connections/unions for sprinkler systems should be installed and hydraulically tested by the escalator manufacturer in accordance with a specification (i.e. diameter of pipework and number/position of sprinkler heads) provided by the specifier, usually the mechanical and electrical consultant.

It is accepted practice that testing of the sprinkler heads and the final system test is carried out by other parties.

Fire shutters, where required by the fire authorities, are provided by specialist subcontractors which, if necessary, can be instructed through the escalator manufacturer. When such devices are installed it is necessary for the escalator manufacturer to include control interfaces to ensure correct and safe operation.

4.10.4 Environmental aspects

Normal escalator design and production relates to applications in enclosed buildings with conventional heating and ventilation systems. Environments in which hazards to either equipment and/or passengers exist must be regarded as special applications requiring non-standard solutions.

The most common 'non-standard' application is outdoor installation whereby the equipment is exposed to the weather. It is recommended that total exposure to the UK climate is avoided. However, canopied installations incorporating proper drainage, waterproofed electrical equipment and corrosion protection can prove satisfactory if maintained in accordance with the manufacturer's recommendations. Note that the level of maintenance required will be much greater than that for an indoor installation, resulting in both time and cost penalties. Suitable allowances for maintenance must be included in specification.

Applications in locations subject to corrosive and/or flammable atmospheres should be avoided since there is no satisfactory design solution to overcome the resulting problems.

4.10.5 Noise and vibration

The design of all escalators and passenger conveyors should be such as to minimise the transmission of vibration to the building structure. This may involve the use of appropriate insulation devices and the manufacturer should be consulted.

Where extreme standards of quietness are required, e.g. in libraries, additional sound insulation may be included to limit airborne noise transmission.

4.10.6 Installation

Where possible, it is beneficial to have the escalator delivered and installed as a single unit. This allows for maximum pre-assembly and testing at the factory, including running-in, and will ensure rapid and efficient installation on site. However, this must be carefully planned if costly installation difficulties are to be avoided. A typical one-piece unit may be more than 16 m long, 1.6 m wide and 3 m high, and weigh up to 9000 kg. Therefore consideration must be given to the following:

- A clear, straight access route onto and across the site must be provided. Normally this should be at least 3 m wide, with a minimum vertical clearance of 3.5 m.
- Police approval will be needed if unloading is to be carried out on a public highway.
- Consideration must be given to permitted floor loadings along access route.
- Suitable hoisting points must be provided.

Early planning is essential, particularly in the case of installations in existing buildings.

4.10.7 Maintenance

Regular and efficient maintenance is essential to ensure that the specified working life is achieved. Due to the high cost of replacement of items such as chains, drive machinery etc. it is preferable to enter into a maintenance contract (see section 12) which includes replacement of mechanical and/or electrical equipment as necessary.

Where glass cladding is used to reveal the moving parts of an escalator, special allowance should be made for regular cleaning, in excess of the usual maintenance costs.

The use of escalators in public places, e.g. in airports, shopping centres etc., requires that special arrangements have to be made to ensure that shutdown for maintenance causes minimum disturbance. An allowance must be made for both the direct cost of maintenance and the associated indirect costs, such as security arrangements for out of normal hours work.

References

1 *BS 5655: Lifts and service lifts: Part 5: 1989: Specification for dimensions of standard electric lift arrangements* (London: British Standards Institution) (1989)

2 *BS 5655: Lifts and service lifts: Part 1: 1986: Safety rules for the construction and installation of electric lifts* (London: British Standards Institution) (1986)

3 *BS 5655: Lifts and service lifts: Part 2: 1988: Safety rules for the construction and installation of hydraulic lifts* (London: British Standards Institution) (1988)

4 *BS 5655: Lifts and service lifts: Part 6: 1990: Code of Practice for selection and installation* (London: British Standards Institution) (1990)

5 *BS 6262: 1982: code of practice for glazing for buildings* (London: British Standards Institution) (1982)

6 *Safety at glass lifts* (Bootle: Health and Safety Executive) (1986 and 1990)

7 *BS 5900: 1991: Specification for powered domestic lifts* (London: British Standards Institution) (1991)

8 *BS 5810: 1979: Code of practice for access for the disabled to buildings* (London: British Standards Institution) (1979)

9 *BS 5588: Fire precautions in the design, construction and use of buildings: Part 8: 1988: Code of practice for means of escape for disabled people* (London: British Standards Institution) (1988)

10 *The Building Regulations 1991* (London: HMSO) (1991)

11 *BS 5655: Lifts and service lifts: Part 3: 1989: Specification for electric service lifts* (London: British Standards Institution) (1989)

12 *Rack and pinion hoists* Certificate of exemption no: Con (LO)/1981/1 (Bootle: Health and Safety Executive) (1981)

13 *BS 5323: 1980: Code of practice for scissor lifts* (London: British Standards Institution) (1980)

14 *BS 5656 (EN 115): 1983: Safety rules for the construction and installation of escalators and passenger conveyors* (London: British Standards Institution) (1983)

15 *Safety in the use of escalators* Plant and Machinery Guidance Note PM 34 (Bootle: Health and Safety Executive) (1983)

16 *Escalators: periodic thorough examination* Plant and Machinery Guidance Note PM 45 (Bootle: Health and Safety Executive) (1984)

5 Firefighting lifts and escape lifts for the disabled

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Contents

5 Firefighting lifts and escape lifts for the disabled

5.1 Introduction

In event of fire, evacuation routes for occupants of buildings are usually via fire resistant stairways. However, provision may still have to be made for a lift to operate during a fire either to enable firemen to access upper floors safely or, in public buildings, to assist in the evacuation of disabled people.

5.2 Need for firefighting lifts

5.2.1 General

A standard lift fitted with a fire service switch cannot be considered as a firefighting lift. The provision of firefighting lifts requires substantial expenditure and therefore the need for such a lift must be properly established.

This section provides guidance on the application of firefighting lifts within different types of building and on the design of the firefighting lifts. Its aim is to provide a basic understanding of the codes and how they affect lifts. It is not, however, intended to be comprehensive and, where appropriate, reference must be made to *The Building Regulations*(1) and relevant *British Standards*(2–18).

5.2.2 History and development

As early as 1930 it was recognised that firemen should be provided with a means of swift access to the upper floors of large buildings. This resulted in conventional passenger lifts being fitted with a break-glass key switch at the fireman's access floor which, when operated, brought the lift to that floor quickly.

It was determined that such lifts should have power-operated doors 2 ft 9 in (800 mm) wide. Their capacity would be 1200 lb (550 kg) and they would be sufficiently fast to travel the height of the building in less than one minute. Additional requirements, such as fire-tested landing doors, rated at 1 hour, were gradually introduced. Some local authorities imposed further specific requirements such as those contained in Section 20 of the *London Building Act 1939*(19).

The main requirements were taken into *BS 2655: Part 1*(2) which was superseded in 1979 by *BS 5655*(3–9).

Although these standards define the basic requirements for 'fireman's lifts', no guidance is given on the circumstances in which such a lift should be provided. This information is contained within *The Building Regulations*(1) and, since 1988, in *BS 5588: Part 5*(13).

It is now recognised that modern firefighting techniques involve the use of equipment which needs to be moved by means of the lift. Furthermore, firemen need a safe and reliable means of access to the upper floors of large buildings. The concept of the firefighting lift was devised to meet these requirements and *BS 5588: Part 5* sets down standards for such lifts. These lifts are referred to as firefighting lifts and the term 'fireman's lift' should no longer be used.

5.2.3 Provision of firefighting lifts in shops

For shops, *BS 5588: Part 2*(10) recommends that in buildings exceeding 18 m in height, firefighting stairways should be provided, each of which incorporates a firefighting lift, so that the distance travelled on any part of any storey above the 18 m level to the nearest firefighting lift, does not exceed 60 m. It also recommends that one firefighting stairway incorporating a firefighting lift should be provided for each 900 m^2 of floor area (or part thereof) on every floor above the 18 m level.

For shops which incorporate large areas of office space either above or below ground, the recommendations of *BS 5588: Part 3*(11) apply. This may result in the need for a firefighting lift even though the recommendations of *Part 2* do not indicate such a need.

Other factors, such as the number of basements, are also relevant in determining the need for a firefighting lift and therefore it is advisable to consult the local fire authority.

While the fire authority's recommendations must be considered carefully, confusion can sometimes arise over the type of lift required, especially in buildings less than 18 m high which fall outside *BS 5588: Part 2*.

In a small three-storey building, the fire authority may suggest that a means of returning the lifts to the ground floor should be provided (for example, by means of a switch marked 'fireman's control'). This does not mean that a firefighting lift is required. Furthermore, small buildings may have firefighting stairways and may also have lifts but the lifts do not necessarily need to be specially designed for firefighting.

5.2.4 Provision of firefighting lifts in offices

BS 5588: Part 3[11] recommends that in office buildings exceeding 18 m in height, firefighting stairways, each incorporating a firefighting lift, should be provided so that the distance travelled from any part of any storey to the nearest firefighting lift does not exceed 60 m, and so that there is one lift for each 900 m^2 of floor area (or part thereof) on any floor above the 18 m level.

The standard also recommends that a firefighting lift is required if basements with a depth exceeding 9 m are provided. In tall buildings, it is not essential that the same lift serve floors above ground as well as basement areas. Again the advice of the local fire officers should be sought.

With building heights of less than 18 m or basements less than 9 m deep, *BS 5588: Part 5*[13] suggests that firefighting stairs are required but a firefighting lift need not be provided. It is often suggested that firefighting lifts be installed in these circumstances. However, this is unwise unless all the other recommendations regarding the building design are also going to be implemented. If it is decided that the recommendations of *BS 5588: Part 5* will be followed, there will be implications for both the building and the lift design.

5.2.5 General requirements of *BS 5588: Part 5*

BS 5588: Part 5[13] first repeats the statement that when the height of a building from the fire service access roadway to the top floor (excluding any storey consisting of plant) exceeds 18 m, or if the depth from the access roadway to lowest level exceeds 9 m, firefighting shafts each containing stairs, lobbies and a lift should be provided. If the height exceeds 7.5 m, or two or more basements each with an area of 900 m^2 or more are planned, firefighting shafts with stairs and lobbies are required. A lift, however, is not needed.

The number of shafts is determined by the length of a fire hose and the standard recommends that sufficient shafts be provided and positioned to give one shaft for every 900 m^2 of floor area on any given storey. The distance between the shaft and the accommodation to any point on the storey must not exceed 60 m. If the internal layout is not known, a direct route of 40 m may be used for planning purposes.

Whilst it is desirable for lifts to serve all storeys of a building, it is not essential. In large complexes, several lifts may provide for firefighting some of which may serve upper floors while others serve basements. Figure 5.1 outlines the extent of travel required by a firefighting lift.

Access to the firefighting lifts from outside the building must be by way of a fire-protected route which provides the same level of protection as that afforded to the lifts and stairs. The route should not be longer than 18 m. For this reason it is usually best to site the firefighting lifts close to the outside walls of the building.

It should be noted that, although passengers may use the lift during normal operation, its primary function must not be for the transportation of goods.

Whichever layout or position is selected, firefighting lifts must be within a fire shaft which contains stairs, lobbies and the lift itself. The entire shaft must be enclosed by a structure which is fire resistant for two hours from outside and one hour from inside the shaft. Figure 5.2 shows a typical arrangement.

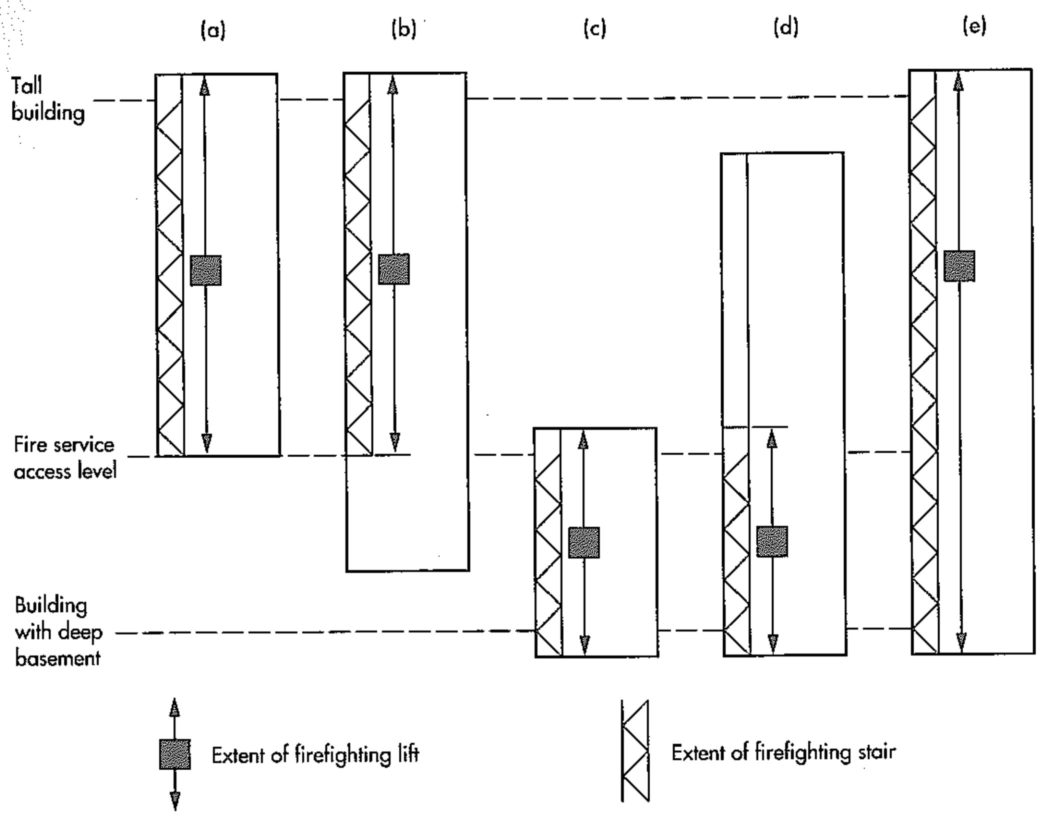

Figure 5.1 Extent of travel of firefighting lift; (a) buildings over 18 m high without basement, (b) buildings over 18 m high with basement less than 9 m deep, (c) buildings with basement only; (d) buildings less than 18 m high with deep basement, (e) buildings over 18 m high with deep basement

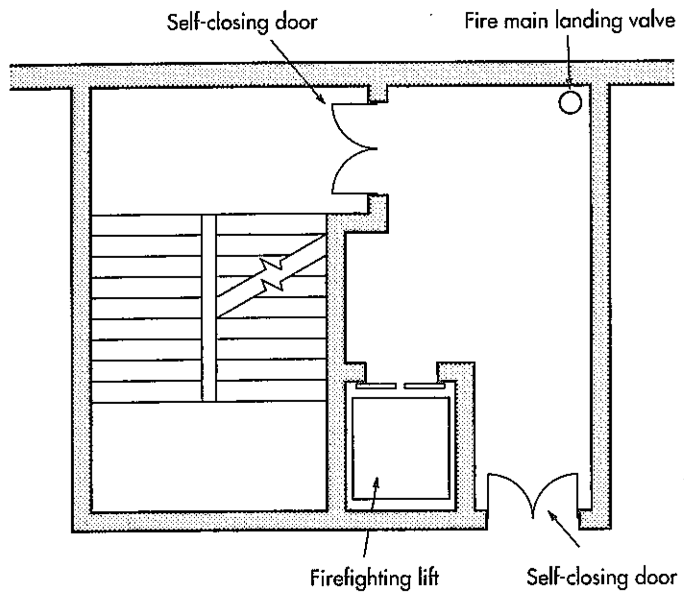

Figure 5.2 Typical layout for firefighting shaft

Without the provision of a lobby or stairs, the ability of a lift to operate during a fire is questionable. It is not possible to ensure that the lift can withstand fire and so a lobby must be provided. In the event of a lift failure an alternative exit must be provided for firefighters, hence the need for stairs.

The firefighting lift may share a common shaft with other lifts, see Figure 5.3, but in such cases it must also share a common lobby and all lifts in the shaft will need to be constructed to a similar standard in terms of the fire resistance of the materials used in the cars and all must have fire resistant landing doors. *BS 5588: Part 5*[13] recommends that there should be a minimum fire resistance of two hours from outside the firefighting shaft and one hour from inside for the structure.

BS 5588: Part 5 provides detailed guidance on the requirements for fire escape routes, stairs and lifts. While detailed consideration of escape routes and stairs is outside the scope of this *Guide* it is important to note that pressurisation of firefighting shafts is recommended in certain circumstances.

Such pressurisation systems should follow the principles given in *BS 5588: Part 4*[14] and the system provided should keep both the firefighting lift well and stair enclosure clear of smoke. In the event of smoke entering the firefighting lobby, the pressure within the stair enclosure should not drive smoke into the lift well or vice versa. This should be achieved by providing separate pressurisation of the firefighting lift well and stair enclosure.

Pressure levels and means of calculation are provided in *BS 5588: Part 4*[12]. These include typical leakage rates through lift doors. It should be noted that it is not

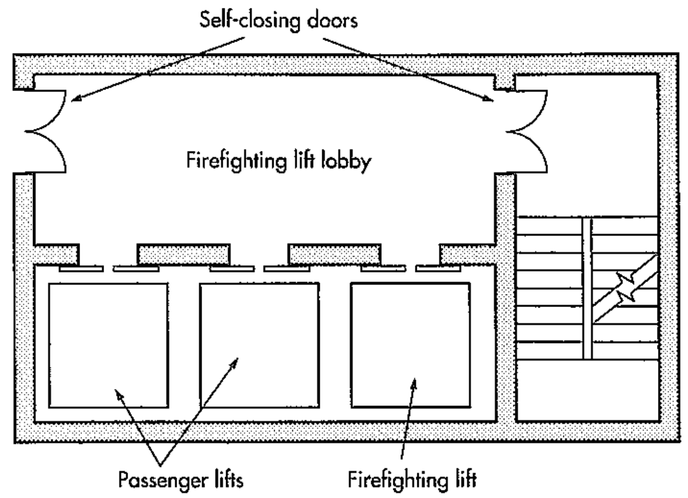

Figure 5.3 Layout of a firefighting cell with shared lift shaft.

practical to seal the lift doors to reduce leakage and the addition of brush or similar seals will generally invalidate the fire certification applicable to the doors. Typical pressure levels for such systems are in the range 30–60 Pa and, while such pressures will not generally disturb operation of the doors, it is advisable to notify the lift supplier of the intention to pressurise the installation and provide details of the likely pressures.

5.3 Design considerations for firefighting lifts

5.3.1 General

BS 5588: Part 5[13] provides detailed guidance on the design of firefighting lifts, including the following:

- Firefighting lifts must be at least 630 kg duty load; the internal dimensions of the car should be 1100 mm wide, 1400 mm deep and 2000 mm high.
- The speed should be sufficient to enable the lift to run the full travel of the building in less than 60 seconds. (An approximation of the minimum speed required may be obtained by dividing the total travel by 60 seconds minus 8 seconds for the car to accelerate and decelerate.)
- Automatic power-operated doors must be provided, at least 800 mm wide by 2000 mm high. A fire rating of one hour is usually required.
- Lift position indicators should be provided both in the car and at the fireman's access level to show the car position at all times while power is available.
- A two-way intercom must be provided between the car, machine room and fireman's access level. It should be switched on automatically when the lift is put to firefighting operation. A handset may be used in the machine room or lobby but the car should contain a microphone and speaker.

- The lift must be clearly marked 'Firefighting Lift' in accordance with *BS 5499: Part 1*[15] and *BS 5588: Part 5*[13].
- An emergency hatch complying with *BS 5655: Part 1*[3] should be provided in the lift car roof.
- Car buttons and controls should not be prone to damage due to water or moisture and, in addition to the normal storey markings, should indicate the fire service access level with 'FSAL' on or near the controls.
- The walls and roof of the car should be constructed from non-combustible materials such as steel. Wall and ceiling linings should be of materials categorised as class 1 in accordance with *BS 476: Part 7*[16].
- Electrical equipment on landings, within the lift car and shaft should be protected against water. Lift equipment is not generally designed and tested for this requirement, nor is it practical to provide protection for every item of equipment. Some level of additional protection should be provided with covers to locks, limits and any other equipment located within one meter of the lobby wall. Such protection, however, will not reduce the need for precautions for landings mentioned in section 5.3.4.
- An audible and visual alarm should be provided within the shaft and machine room to alert maintenance engineers of operation of the firefighting switch while on inspection control.
- In the event of loss of the mains supply and establishment of the secondary supply, the lift must re-establish its position within 10 seconds without returning to the fireman's access floor.
- Firefighting lifts must meet the requirements of *BS 5655*[3–9] in all other respects.

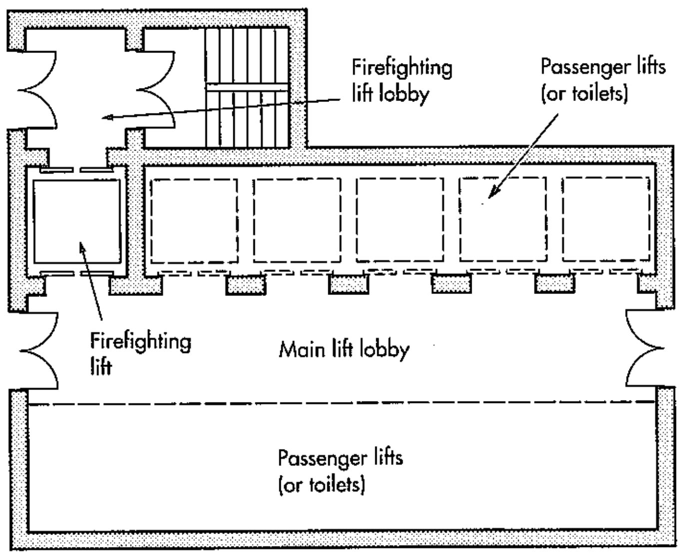

Figure 5.4 Provision of additional fire lobby for a dual-entry car

5.3.2 Car entrances

Cars for firefighting lifts should preferably be front opening, i.e. entrance to the car is from one side only. If a dual-entry lift with front and rear openings must also serve as the firefighting lift, additional precautions for the rear entrance will be required and it is usually necessary to provide a second fire lobby, as shown in Figure 5.4. However, the additional cost of such arrangements must be carefully considered. The advice of the local building control officer and fire officer should be sought.

5.3.3 Machine room location

The lift machine or pump room should preferably be sited above the lift shaft and access should be via the firefighting stairway adjacent to the lift.

If it is essential to locate the machine or pump room at the bottom of the building, it should be towards the rear or side of the shaft rather than directly below where it is vulnerable to falling water. Access to such machine rooms should still be via a fire protected route, preferably the firefighting stairway.

Holes in walls or floors separating machine rooms from lift shafts should always be kept to a minimum. Water must be prevented from entering the machine room.

5.3.4 Protection of lift shaft from water

The most likely source of water will be from fire hoses or accidental discharge from risers located in the lift lobby. The flow rate from such sources may be assumed to be about 25 litres per second. Every effort must be made to prevent this water from entering the lift shaft. Floors in the fire lobby should be sloped away from the lift, with drains or scuppers provided to remove water from the immediate area in front of the lift doors. Water should also be directed away from stairways.

Risers should be directed away from lift doors but it is inevitable that there will be at least minor spillages which will find their way into the lift shaft. For this reason it is necessary to provide some degree of water protection to any electrical components in the lift.

BS 5588: Part 5[13] recommends that protection be provided to electrical lift equipment in the shaft that is located within 1 m of the lobby. The protection should cater for splashing water and may be satisfied by either shrouds and covers or by providing IPx3-protected equipment that meets the requirements of *BS 5420*[17]. However, this is a low level of water protection and it is vital that every effort be made to reduce the risk of spillage into the lift shaft.

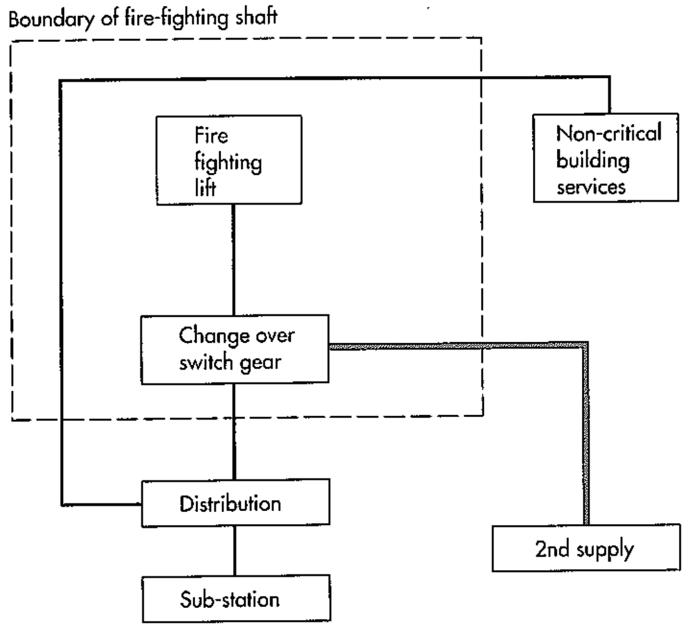

Figure 5.5 Block diagram for independent power supplies to firefighting lifts

Attempting to provide a higher degree of protection in the hope of avoiding the need for sloping floors or gullies is not reasonable because, whilst it may be possible to provide complete protection from water, the resulting lift design may no longer comply fully with *BS 5655*[3–9].

5.3.5 Power supplies

Two independent power supply systems are always required. The primary electrical supply should be from a sub-main circuit exclusive to the lift and independent of any other main or sub-main circuit, see Figure 5.5. Other lifts in the firefighting shaft may be fed from the same primary supply, provided that the supply is adequate for the purpose. Such an arrangement must be designed so that a fault occurring in any other lift in the firefighting shaft, or in the power supplies to any of these lifts, will not affect the operation of the firefighting lift.

The secondary power supply should be independent of the normal power supply to the firefighting shaft, e.g. a different substation or a standby generator (with automatic start). The lift supplier should not be asked to provide this secondary supply since it serves not only the lifts but also the firefighting shaft and the lift supplier cannot be expected to know what other plant is to be connected to it.

The secondary supply should have sufficient capacity to:

- maintain the firefighting lift in operation for at least three hours
- support any auxiliary equipment such as ventilation or pressurisation plant
- be able to recover all other lifts, one at a time if necessary, within the firefighting lobby.

The secondary supply should be available within 30 s of the loss of the normal supply. The supplies must be via fire-protected routes with the same level of protection afforded to the lift by the structure, usually two hours. Cables for these supplies should be terminated in an automatic supply change-over device that may be located in the firefighting shaft (see *BS 5588: Part 5*[13]) but this does not mean in the lift shaft itself.

5.3.6 'Fireman's' switch

A switch located within a locked metal cabinet marked 'FB' should be positioned adjacent to the lift entrance at the fire service access level. The switch, which may be of the toggle type, must be clearly visible when the cabinet is opened and marked 'Firefighting Lift'. The 'on' and 'off' positions must be clearly marked.

Operation of the switch puts the lift into firefighting service, as follows:

- All special services except inspection are ignored. All lifts within the firefighting shaft must return to the fire access level without stopping and display a car sign during this operation stating 'Lift under fire service control'.
- When a car arrives at the fire service access level, it discharges its passengers and then closes its doors. With the exception of the firefighting lift car, the lifts will not respond to any other calls.
- All landing and car calls are inoperative except for car calls in the firefighting car. On dual-entry cars only the doors on the firefighting lobby side will be operative (see section 5.3.2). Door detectors are made inoperative and the intercom system is switched on automatically.
- If a call is entered in the firefighting lift car, it responds to that call and no other. While the car is in motion, it should be possible to enter other car calls and thereby stop the car in response to the first call registered.
- When the car stops at a call, this cancels that call and all others. When the lift stops at a floor its doors open only when its door button is pressed and if the button is released while the doors are opening, they immediately re-close.
- Once fully open, the doors close only in response to constant pressure on another car call button. If this button is released before the doors are closed, they re-open. The buttons must illuminate to indicate any call that is registered. Alternatively, a separate indicator light may be provided.

5.4 Inspection, testing and maintenance of firefighting lifts

5.4.1 Operational tests prior to handover

Appendix C of *BS 5588: Part 5*[13] gives detailed guidance on how firefighting operational tests should be carried out. The lift supplier may need to carry out additional tests to satisfy themselves that the lift fully meets these requirements. When complete a test certificate should be issued which forms part of the general documentation for the lift.

5.4.2 Routine inspection and maintenance

Once in service, the lift along with all other firefighting equipment and services should be regularly inspected. For the lift the following checks are recommended.

5.4.2.1 Weekly check

Operation of the firefighting lift switch by the building maintenance staff who should check that the lift returns to the lobby and parks with its doors open. Failure in this simple test should be reported immediately to the lift maintenance company.

5.4.2.2 Monthly check

Simulate failure of the primary power supply. Building maintenance staff should then operate the firefighting lift switch and observe its operation by entering a few calls. The lift maintenance company may be asked to be present at these tests but their presence will probably incur additional charges.

5.4.2.3 Six-monthly inspection

Inspection and testing by the lift maintenance company should be made as recommended in *BS 5655: Part 10*[8].

5.4.2.4 Yearly inspection

Operation of the lift should be performed as described in Appendix C1 of *BS 5588: Part 5*[13]. Whoever carries out this test should again complete a test certificate. This test may not be part of a normal maintenance contract and this point should be clarified whenever a maintenance/service contract is agreed otherwise additional charges may be imposed.

5.5 Escape lifts for the disabled

5.5.1 General

While planning fire prevention and escape routes for a building, consideration must be given to escape for disabled persons who may use the building. In the event of a fire, the occupants will usually evacuate a building by means of stairways but alternative routes for the evacuation of people with impaired mobility may need to be provided.

This section provides guidance for the design of lifts intended to be used for the purposes of escape as given in *BS 5588: Part 8*[14]. While the type of building and its use will determine whether disabled people need to be catered for, those responsible for building control may also require that such provision be made.

5.5.2 Access/egress for the disabled

The Disabled Persons Act 1981[20] includes a requirement that provisions for access to public buildings comply with *BS 5810*[18]. Implementation of this Act is achieved by means of *The Building Regulations*[1].

It is a requirement of UK building legislation that access provision must be linked to egress provision and, since lifts were already being used to provide access for disabled, concern was expressed over the possible use of such lifts for escape. In response to this concern, *BS 5588: Part 8*[14], was produced.

This standard provides detailed guidance for evacuation procedures and on the types of lift required. Although wheelchairs and stair lifts fitted to a stairway may be suitable for access, they are not suitable for use as a means of escape and therefore are excluded by the standard. Furthermore, stair lifts may impair evacuation if they reduce the usable width of stairways. Escalators are also excluded as a suitable means of escape, both for disabled and able-bodied persons.

BS 5588: Part 8 recommends that the lift be operated under the direction and control of authorised persons using an agreed evacuation procedure and the successful operation of escape lifts is very dependent upon the competence of the lift operator and the effectiveness of the building management procedure. Only disabled persons should use the lift because fixed stairs are still considered as the appropriate means of escape for able-bodied persons. It is not intended that the disabled evacuate themselves from the building unaided, even where a lift is provided, and other means such as the provision of a refuge may be considered.

Fire procedures should not include the isolation of electrical circuits that supply the lift or its lighting, communication or ventilation. Any ramps used to allow changes in level or to allow entry into lifts should comply with *BS 5810*[18] in terms of slope and size.

5.5.3 Design considerations

BS 5588: Part 8[14] makes the following recommendations concerning the design of lifts suitable for the evacuation of disabled people:

— The lift car must be of at least eight-person capacity, and 1100 mm wide by 1400 mm deep.

— The lift must be sufficiently fast to run the full travel of the building in less than 60 seconds.

— Power-operated doors must be fitted, providing an opening of at least 800 mm by 2000 mm. The doors should provide protection from fire for at least half an hour.

— There must be two separate fire-protected power supplies. However, two-stop hydraulic lifts may not require an alternate means of supply since they can be manually lowered and may not require a special switch to enable the lift to be quickly brought to the main lobby.

— The car must be made of substantially non-combustible materials.

— All controls must be at wheelchair height and a handrail must be provided.

— A communications system must be provided between the car and the machine room and the main lobby.

— A break-glass switch, marked 'Evacuation Lift', should be located at the final fire exit floor. Operation of this switch should cause the lift to slow down, stop and return to the main evacuation floor without undue delay. While returning it should be prevented from answering any landing calls and, once at the lobby, it should park with its doors open and then respond only to car calls. The lift should be under the sole control of the user.

In some circumstances, *BS 5588: Part 8*[14] allows alternatives to a separate escape lift, as follows:

— A firefighting lift (i.e. a lift to *BS 5588: Part 5*[13]) which the fire brigade has agreed may be used prior to their arrival.

— In existing buildings, with the prior agreement of the fire authority, a normal passenger lift may be used provided it is of suitable size, has the same structural protection as a protected stairway, a duplicate power supply, a switch enabling authorised persons to take control and an agreed management procedure for its use during a fire.

5.5.4 Communication system

BS 5588: Part 8[14] recommends that, except in two-storey buildings, some form of communication system should be provided to enable the rapid and unambiguous identification of those storeys with disabled persons requiring evacuation, and the relaying of this information to the persons operating the evacuation or firefighting lift.

Such a system may consist of a control sited at each lift landing linked to the lift car call indicators. Alternatively, requests may be made by the persons requiring assistance to the person controlling the evacuation using visual indicators or by telephone, and these may then be relayed to the lift operator by telephone intercom or radio transceiver.

Communication is a key item during a fire and simple systems generally prove the most reliable. For example, at each landing, adjacent to the lift, there could be a telephone system which connects it to the lift main evacuation lobby. When the lift is required for a particular floor, the person responsible for the evacuation of the disabled from that floor can request the person in charge of the main lobby to despatch the lift who relays the message to the lift driver by an intercom system.

An alternative or addition to this would be the provision of a break-glass switch of the push/pull type at each floor. When pushed it would latch and light an indicator lamp at the main landing. Resetting of the switch would be done manually by the person responsible for entering the call.

The provision of complex automatic systems is unnecessary because it is not intended that disabled persons should evacuate themselves from the building.

References

1 *The Building Regulations 1985: Mandatory rules for means of escape in case of fire* (London: HMSO) (1985)

2 *BS 2655: Specification for lifts, escalators, passenger conveyors and paternosters: Part 1: 1970 (obsolescent): General requirements for electric, hydraulic and hand-powered lifts* (London: British Standards Institution) (1970)

3 *BS 5655: Lifts and service lifts: Part 1: 1986: Safety rules for the construction and installation of electric lifts* (London: British Standards Institution) (1986)

4 *BS 5655: Lifts and service lifts: Part 2: 1988: Safety rules for the construction and installation of hydraulic lifts* (London: British Standards Institution) (1988)

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10 *BS 5588: Fire precautions in the design, construction and use of buildings: Part 2: 1985: Code of practice for shops* (London: British Standards Institution) (1985)

11 *BS 5588: Fire precautions in the design, construction and use of buildings: Part 3: 1983: Code of practice for offices* (London: British Standards Institution) (1983)

12 *BS 5588: Fire precautions in the design, construction and use of buildings: Part 4: 1978: Code of practice for smoke control in protected escape routes using pressurization* (London: British Standards Institution) (1978)

13 *BS 5588: Fire precautions in the design, construction and use of buildings: Part 5: 1986: Code of practice for firefighting stairways and lifts* (London: British Standards Institution) (1986)

14 *BS 5588: Fire precautions in the design, construction and use of buildings: Part 8: 1988: Code of practice for means of escape for disabled people* (London: British Standards Institution) (1988)

15 *BS 5499: Fire safety signs, notices and graphic symbols: Part 1: 1990: Specification for fire safety signs* (London: British Standards Institution) (1990)

16 *BS 476: Fire tests on building materials and structures: Part 7: 1987: Method for classification of the surface spread of flame products* (London: British Standards Institution) (1987)

17 *BS 5420: 1977 (1988): Specification for degrees of protection of enclosures of switchgear and controlgear for voltages up to and including 1000 V a.c. and 1200 V d.c.* (London: British Standards Institution) (1988)

18 *BS 5810: 1979: Code of practice for access for the disabled to buildings* (London: British Standards Institution) (1979)

19 *London Building Act 1939* (London: HMSO) (1939)

20 *Disabled Persons Act 1981* (London: HMSO) (1981)

6 Lift drives, components and installation

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6 Lift drives, components and installation

6.1 Introduction

This section provides an explanation of lift drives, the main components used in modern lifts, both electric traction and hydraulic, and their basic installation requirements.

Lift drives are divided into two categories, electric traction and hydraulic, and both types are considered in this section.

The main components of the elevator are its prime mover (machine or hydraulic pump, depending on the type of drive), the lift car, counterweight (if used), guide rails, entrances, safety gear and governor, buffers, ropes and fixtures (i.e. buttons, indicators and switches).

Figures 6.1 and 6.2 indicate typical arrangements and components for electric traction and hydraulic lift systems. Many variations of these basic arrangements are possible but the component parts are fundamentally the same.

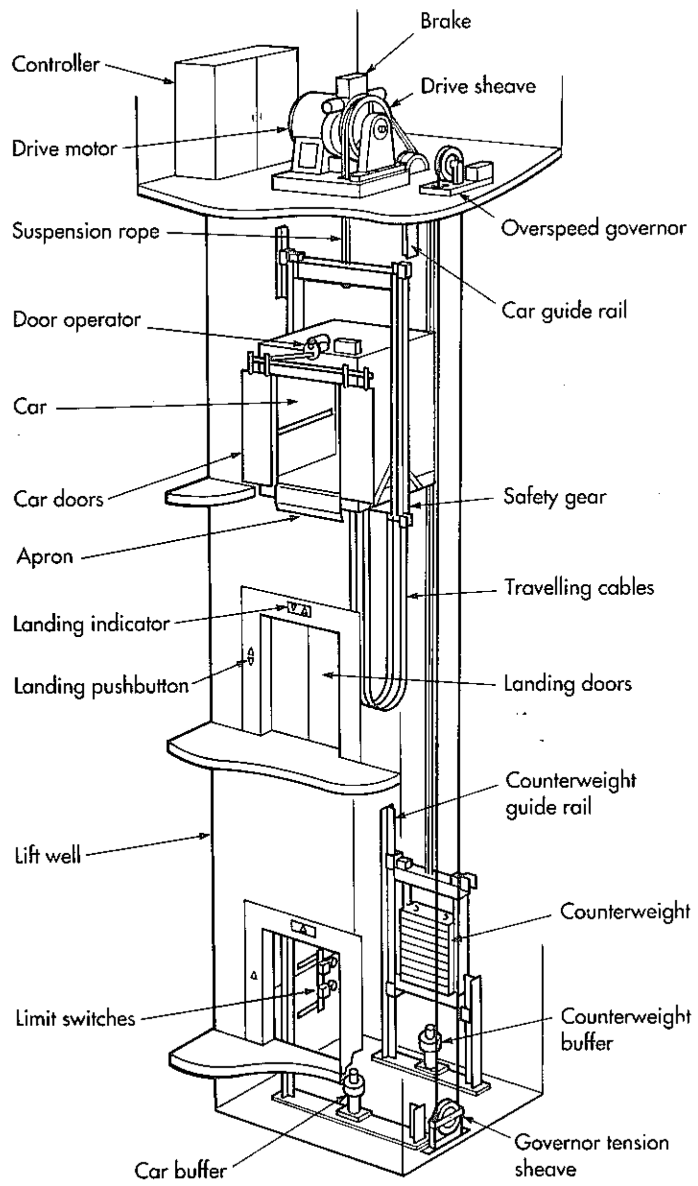

Figure 6.1 Electric traction passenger lift — principal components

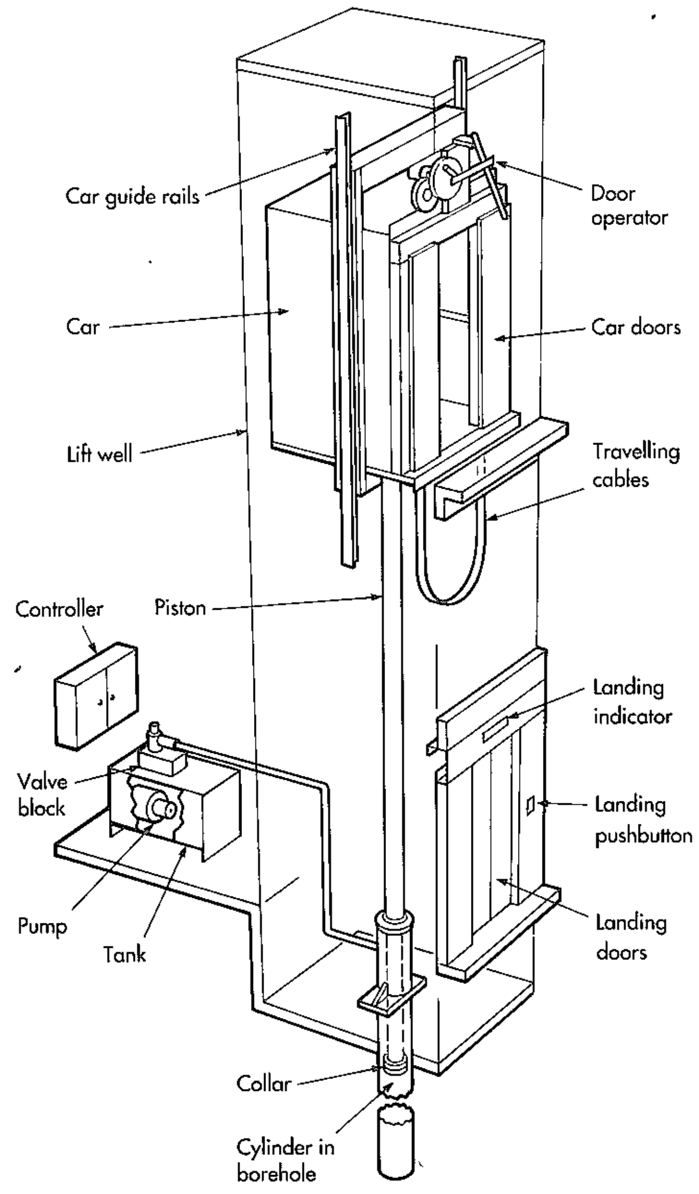

Figure 6.2 Hydraulic passenger lift — principal components

6.2 Electric traction drives

6.2.1 General

Electric traction drives can be grouped into several categories based on the motor type and its control.

Geared traction drives:

- single-speed AC motor
- two-speed AC motor
- variable voltage AC motor
- variable voltage, variable frequency AC motor
- variable voltage DC motor.

Gearless traction drives:

- variable voltage DC motor
- variable voltage, variable frequency AC motor.

Historically, the required lift speed and ride quality have determined to a large extent which type of drive is used for a particular application. With solid-state control incorporating feedback techniques (see section 7.3.3), good ride comfort and levelling accuracy can be obtained for all types of electric traction lift without large cost penalties.

In the past, DC motors have provided the best ride quality because the speed of the motor can be easily controlled using a DC generator with a variable output (see section 7.4.4). Consequently, DC motors have been used for the majority of applications requiring a smooth ride and accurate levelling. During the 1980s, static converters have been replacing DC generators as the means of supply for large DC motors. Compared with DC generators, static converters are more efficient and provide improved control (see section 7.4.4.2).

Improvements in the control of AC motors mean that good ride quality may now be achieved using AC motors. Some manufacturers now use AC motors with helical or worm reduction gearboxes to attain speeds of up to 2.5 m/s. Advanced voltage and frequency control techniques have also led to the introduction of AC gearless motor drives. These provide ride quality to match DC gearless machines for speeds of 2.5 m/s and above.

6.2.2 Gearless machines

The assembly comprises a drive motor, drive sheave, bedplate, brake, direct current armature (or rotor in the case of AC drives, supporting bearings and, possibly, a deflector or double wrap sheave. Gearless machines are generally used for high-speed lifts, i.e. speeds from 2.5 m/s to 10 m/s. They are, however, sometimes used at lower speeds for special applications.

Figure 6.3 shows a typical gearless machine. Size, shape and weight may vary considerably between manufacturers but the basic principles and components will be the same.

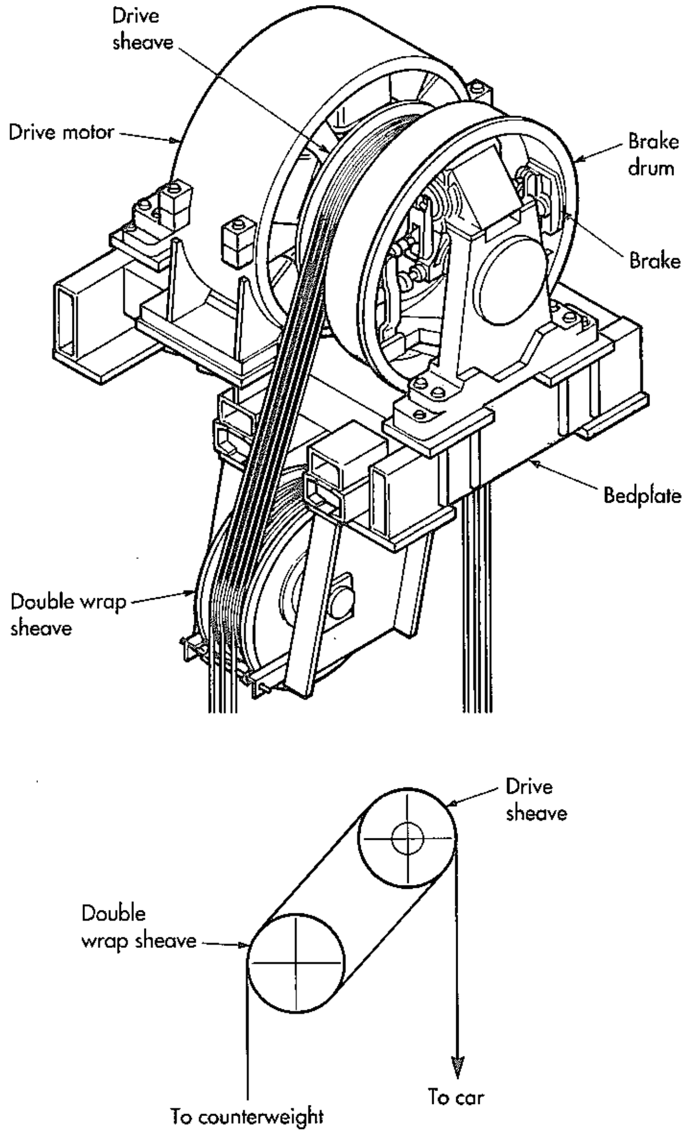

Figure 6.3 Typical gearless machine

Until recently, the motor in gearless machines has always been of the DC type but, with the development of high-speed variable frequency drives, AC motors are being introduced. Whichever type of motor is employed, the power developed will be transmitted directly to the driving sheave which is located on the same shaft as the motor. Hence the sheave rotates at the same speed as the motor. The main shaft will be supported on two large bearings that may be of the sleeve, roller or ball race type.

The brake drum is usually formed as an integral part of the driving sheave and this may be one of several types, depending on the type of brake, e.g. external calliper, internal calliper or disc. Each type has advantages and disadvantages but the main consideration is that the type used must satisfy the relevant code requirements for the country in which it is to be installed. For the UK, the requirements of *BS 5655: Part 1*(1) must be satisfied; i.e. it must be capable of stopping the car when carrying 125% load at full speed.

The brake is used only during emergency stopping and when at rest to hold the lift car during loading. Under

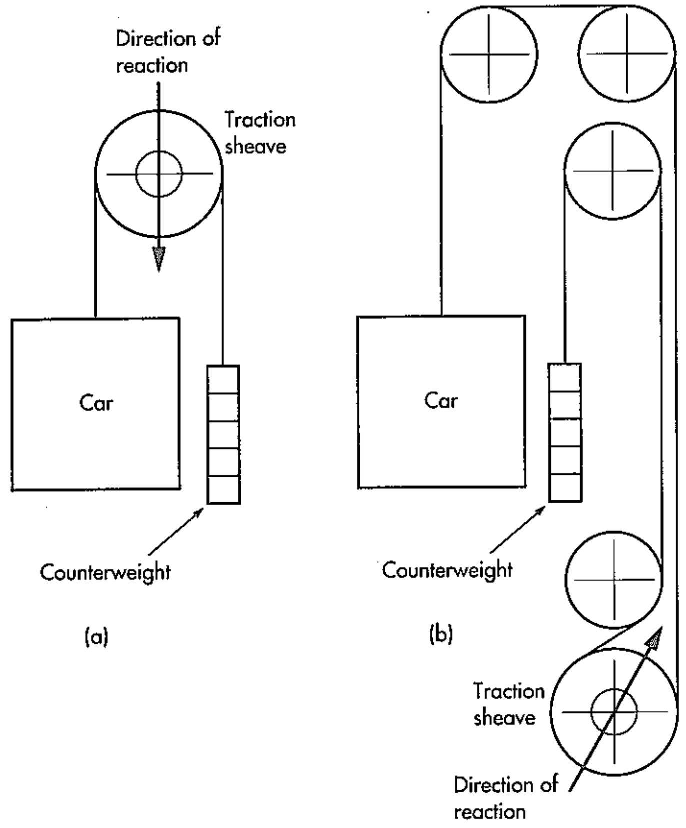

Figure 6.4 Sheave shaft load; (a) machine above with load acting directly downwards, (b) machine below with load acting upwards

normal operating conditions, speed controls are employed to bring the car to rest without the use of the brake. This means that the brake is generally little used and the linings will be slow to bed-in if hard materials are selected. For this reason, and because of the low rotational speed of such units, a relatively soft material is used.

6.2.2.1 Sheave shaft load

The load lifting capabilities of the machine are not limited by the power of the motor alone. During the design, certain bearings, bolts, steel section and grades of steel will have been selected for the construction of the unit. The materials used and the way in which the components are assembled will place a maximum limit on the load that the main shaft can support safely. This is referred to as the sheave shaft load.

The sheave shaft load capability of the machine will vary depending upon the direction in which the load is applied. If the machine is located at the top of the building, with the load acting directly downwards, see Figure 6.4(a), the unit will generally be able to support a higher load than if the ropes are deflected as shown Figure 6.4(b). Locating the machine at the bottom of the building usually results in an upward pull which can drastically reduce the sheave shaft load capability. This may necessitate the use of a much larger machine than was first envisaged. Standard layouts and other arrangements are considered in section 6.2.5.

6.2.2.2 Drive sheave

Gearless machines employ either a sheave cut with a specially formed traction groove (see section 6.14.3, see Figure 6.35), or are double wrapped, whereby the lift ropes pass over the drive sheave twice, see Figure 6.6.

Each method has its merits and will provide the required grip to move the car and, if properly designed, ensure a long rope life. The main disadvantage of the double wrap method is that it takes up additional space since either a secondary chamber must be provided or the unit must be raised to facilitate servicing of the double wrap sheave. However, with very large loads or speeds greater than 4 m/s, it is often the only method available.

As gear reduction is not employed, the rope speed is equal to the circumference of the drive sheave multiplied by the rotational speed (rpm) of the motor. A sheave diameter of 620 mm requires a motor of only 77 rpm to achieve 2.5 m/s. Gearless units have a slow rotational speed compared with geared machines, therefore sound isolation between the machine and structure is not usually required.

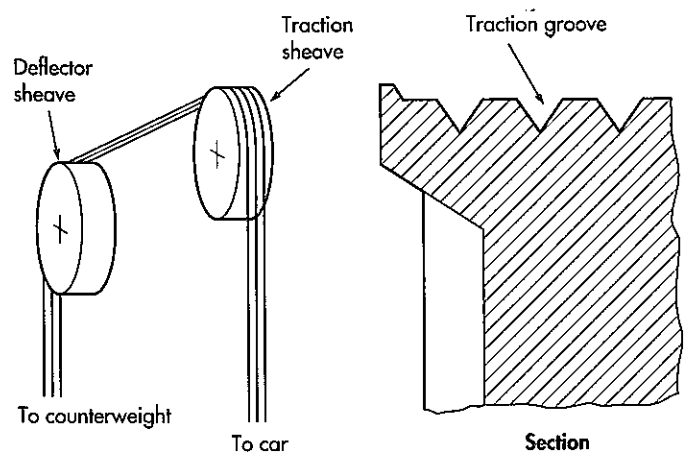

Figure 6.5 Single wrap arrangement with 'V' traction groove and detail of traction sheave

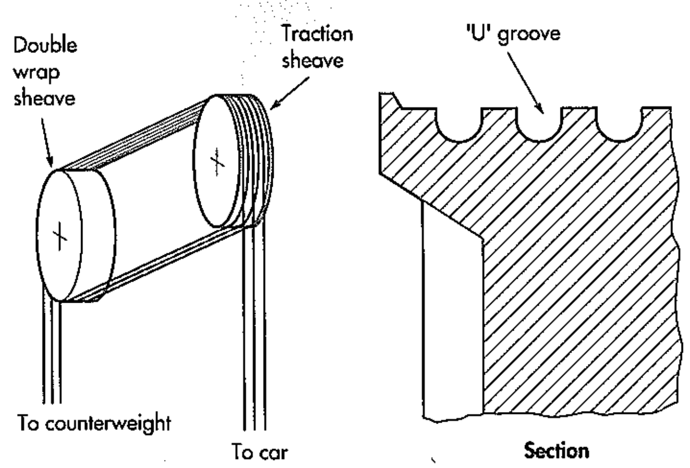

Figure 6.6 Double wrap arrangement with 'U' groove and detail of traction sheave

6.2.3 Geared machines

These comprise a traction sheave or drum, gearbox, brake, motor and bedplate. It may also include a deflector sheave if mounted as an integral part of the bedplate assembly, see Figure 6.7. Strictly, however, the deflector sheave is not part of the machine assembly.

Geared machines are generally used for speeds between 0.1 m/s and 2.5 m/s and are suitable for loads from 5 kg up to 50 000 kg and above.

Size and shape vary considerably with load, speed and manufacturer, but the underlying principles and components are the same.

6.2.3.1 Motor

The motor may be of the AC or DC type, either foot- or flange-mounted. Foot-mounted types are available in a wide selection of sizes and makes, while flange mounting provides accurate alignment and, usually, a more compact design. There are no outstanding advantages for either type but for certain applications one particular type may be preferred. For example, for an elevator on a ship a foot-mounted motor would be preferred because of the greater availability of spare parts throughout the world.

Whichever arrangement or motor type is employed, the motor transmits its power to the traction sheave or drum via reduction gear.

6.2.3.2 Worm shaft

Worm reduction gear, comprising a worm shaft, cut with a coarse helical thread, and a worm wheel, is still the most common worldwide although helical gears have recently started to appear.

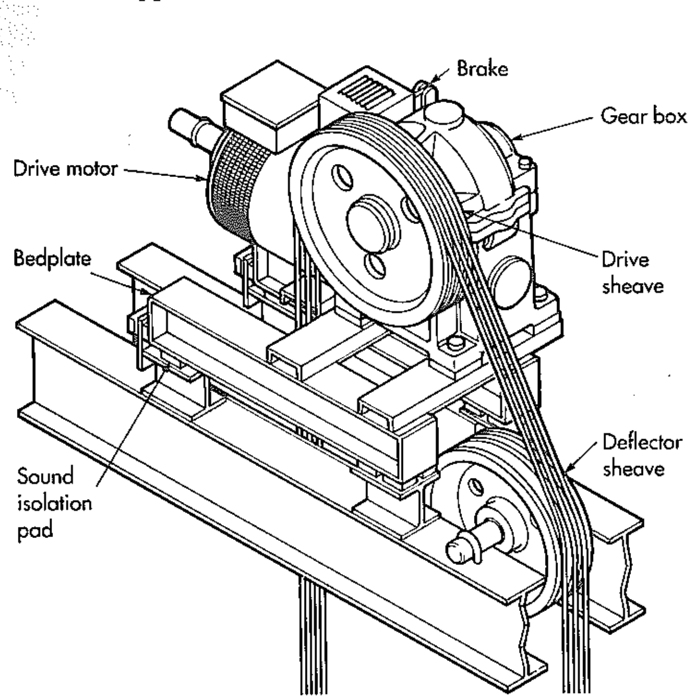

Figure 6.7 Typical geared machine

The worm shaft has a high running speed compared with that of the worm wheel and therefore is made from either case-hardened or high-grade carbon steel. Both these steels have advantages and disadvantages, but the essential requirement is the smooth running and long-life of the finished assembly. Therefore manufacturers choose materials best suited to the particular application.

The worm wheel can be made from various materials but bronze is by far the most common and has considerable advantages over the alternatives. The performance and reliability of the complete unit is more important than the materials employed for the component parts.

The worm may be cut with one, two, three or more threads or 'starts'. The number of teeth on the worm wheel divided by the number of starts on the worm determines the ratio of the gear. For example, 48 teeth on the wheel and 4 starts on the worm gives a ratio of 12:1.

By selecting different ratios a large combination of speeds and loads can be obtained from a single machine type. Each manufacturer has its own selection of ratios for a particular machine and it is not practical to specify a special ratio as any new design will usually require expensive retooling and extensive testing.

The worm may be mounted vertically or horizontally, either above or below the worm wheel. Again each arrangement has its merits but none has any significant disadvantage. The worm shaft will be supported by two bearings of its own or utilise one of the motor bearings. Whichever arrangement is selected, one of the bearings will act as a thrust bearing to prevent the worm from moving laterally. Depending on the design, a thrust movement of one or two thousandths of an inch may be allowed; in other cases no movement is tolerated. The manufacturer's requirements must always be met in this respect.

6.2.3.3 Worm wheel

The worm wheel will be supported on bearings, one of which may be either inboard or outboard of the traction sheave which is mounted on the same shaft. There is much argument as to the merits of inboard and outboard bearings. For example, the inboard bearing allows easy replacement of the sheave while the outboard bearing allows easy servicing of the bearing. The maintenance aspect, however, is insignificant since both components, if properly designed, will provide long service and neither arrangement should require frequent dismantling.

One of the main shaft bearings will also serve as a thrust bearing to limit the shaft's lateral movement. Again, the manufacturer's tolerances should be accepted.

6.2.3.4 Gear life

As with the gearless units described in section 6.2.2, the load lifting capabilities for geared machines will be limited by the motor size, the load capacity of the main shaft and its bearings (sheave shaft load), and the load and

kilowatt capacity of the gearbox. The gears will have been designed to transmit a certain amount of power for a given life. The life will be reduced by the transmission of excessive power or extended if reduced power is transmitted. While worm gears may appear simple their design is complex and there is much debate on the calculation of gear life.

BS 721[2] provides a basis for such calculations, but needs some modification to be realistic for lift gears. To make the calculation of gear life meaningful it is necessary to determine the load carried and the period for which it is carried. In a lift, the load is constantly varying between very light (i.e. empty car) and full load. The gear is not running in the same direction continuously and, for large portions of the day, it is not running at all. Most lifts spend more time at rest, being loaded and unloaded, than running.

It is easy to 'over-engineer', adding unnecessary costs to the installation, by assuming worst-case conditions, such as full load for the life calculation.

At present, gear life is usually expressed in hours, with 15 000 to 20 000 hours being typical. This roughly equates to 15 to 20 years for a lift serving the average office building. It may be tempting to select a higher figure than this, but longer life is achieved by oversizing the gear which results in extra costs. In most commercial buildings, lifts are modernised or replaced after 15 to 20 years. At this time, the main components of the gear can also be replaced. If a 25-year gear life is selected, it is likely that the gear will be overhauled at the time of modernisation of the lift even though it will not yet be near the end of its design life.

6.2.3.5 Drive sheave

The power transmitted by the gear results in rotation of the worm wheel shaft to which the traction sheave or drum is attached. These items are usually fixed to the main shaft by keys and bolts.

The sheave material is sometimes simple cast iron, but is more usually a complex alloy providing a combination of properties such as machineability, strength, coefficient of friction and durability. The aim of the traction system should be to provide sufficient traction to hoist the car while ensuring good rope life. These criteria are affected by the rope size and type, rope pressure, sheave material, sheave groove type, acceleration rate, and the presence of pollutants and abrasives in the atmosphere.

Most manufacturers have, through experience, determined the best combination of these criteria for their particular design and should not be required to use particular materials or rope types that they do not usually employ.

Premature rope or sheave failure is more often due to unequal rope tension than any other single factor and good maintenance is therefore essential. It is not unreasonable to expect the sheave to last the life of the machine provided it is correctly serviced.

6.2.3.6 Brake

At some position along the motor or worm shaft a brake drum will be provided. The usual locations are between the motor and gear or on the opposite end of the gear to the motor, see Figure 6.7. The requirements for the brake vary according to the drive system.

Simple one- and two-speed drives will use the brake for stopping at floors and for emergency stops. With more sophisticated motor controls, the brake may be used only for emergency stopping and parking. Whichever braking system is adopted, it must satisfy the requirements laid down in *BS 5655: Part 1*[1], i.e. it must be capable of stopping the car when carrying 125% load at full speed.

6.2.3.7 Bedplate

The gearbox, motor and brake may be assembled on a common bedplate. This fabricated steel structure serves to keep all parts in accurate alignment and allows one-piece shipment. It is important that the bedplate does not deflect under load thereby causing misalignment of the motor and gear. Some machines have the motor and brake as an integral part of the gear case, removing the need for a separate bedplate.

Properly designed and installed machines should be free from perceptible vibration and unusual noises. Markings on worm wheel teeth should be at or near the centre of the teeth. Any worm shaft float or worm-to-worm wheel

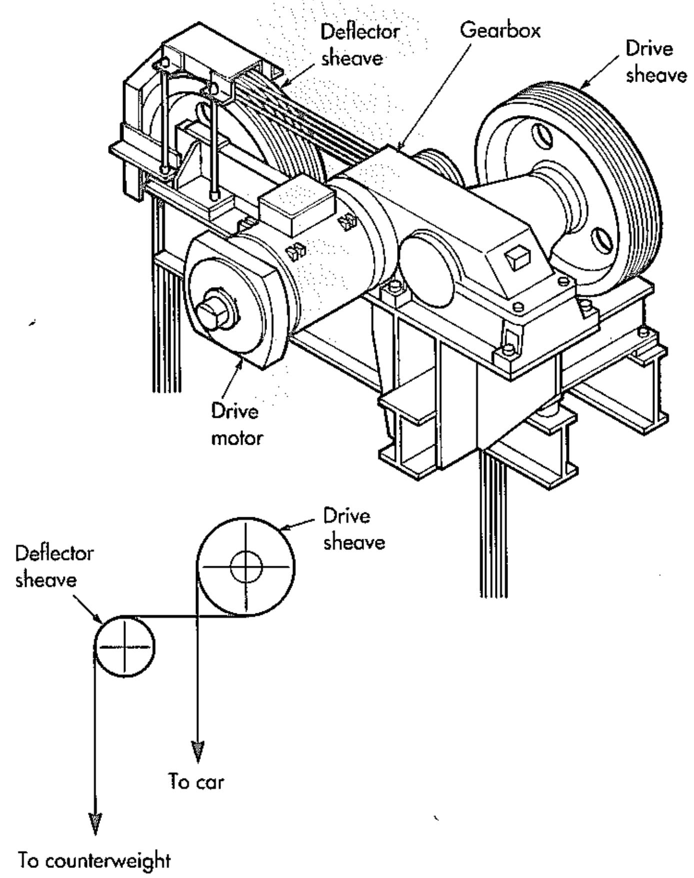

Figure 6.8 Typical longwrap machine and schematic showing rope path

backlash (running clearance between meshing teeth) should not be audible in the machine room or felt within the lift car.

The complete assembly will usually be mounted onto isolation pads to separate it from the building structure. This may not be necessary in the case of bottom drive machines fixed to a solid foundation.

The unit should be installed with its sheave plumb and located within ± 2 mm of its required position. Some manufacturers may employ a roping system (i.e. 'overwrap' or 'longwrap') that requires the sheave to be at an angle to the horizontal to avoid chafing of the rope, see Figure 6.8. In this case the sheave angle should be as recommended by the manufacturer.

6.2.4 Planning and layout

Layout dimensions for electric traction lifts are detailed in *BS 5655: Part 5*[3]. These dimensions should be used where possible because they are suitable for all lift equipment supplied by reputable manufacturers. The dimensions, however, may be modified provided that careful appraisal of equipment and design is undertaken to ensure that the minimum clearances required by *BS 5655: Part 1*[1] are achieved. It should be noted that deviating from the dimensions given in *BS 5655: Part 5* may result in additional costs because non-standard components may have to be fabricated.

The plan dimension of the lift well may increase if bottom drive and/or counterweight safety gear are to be incorporated, see section 6.6.3.

BS 5655: Part 11[4] should be consulted when modernising lifts or installing new lifts in existing buildings. This standard provides guidance on reduced clearances for situations where structural constraints exist.

6.2.5 Machine position

BS 5655: Part 5[3] gives standardised layouts utilising the preferred top drive arrangement, i.e. where the lift machinery is positioned directly above the lift shaft, see Figure 6.9(a).

Other machine positions can be utilised to minimise headroom requirements. However, each of the alternative options may have implications in terms of additional costs, reduction in rope life, increased running noise or a poorer standard of ride comfort.

Pulley arrangements are illustrated in Figure 6.34, see section 6.14.

6.2.5.1 Top drive: machine adjacent

The machine is positioned adjacent to the shaft at high level, see Figure 6.9(b). A series of pulleys is utilised to achieve the correct rope alignment in the shaft below (see section 6.14).

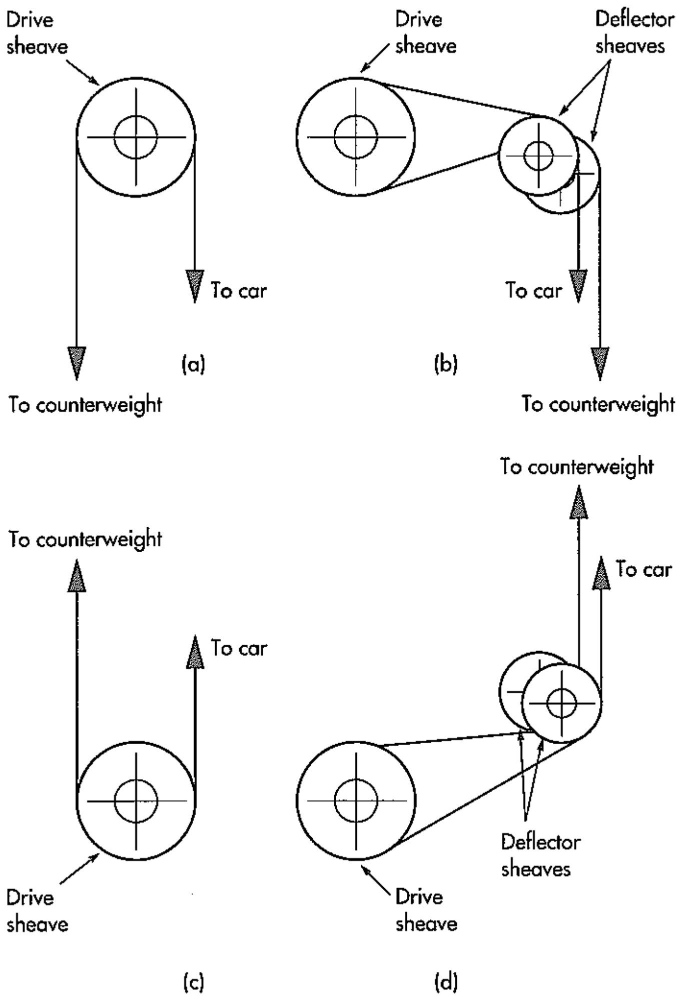

Figure 6.9 Machine position; (a) top drive, machine above, (b) top drive, machine adjacent, (c) bottom drive, machine below, (d) bottom drive, machine adjacent

6.2.5.2 Bottom drive: machine below

The machine is positioned directly below the lift shaft, see Figure 6.9(c). The ropes extend the full height of the lift shaft to overhead pulleys which provide the correct rope alignment to the lift car and counterweight below.

The overhead pulleys may be positioned in a pulley room directly above the lift shaft. Such pulley rooms require a minimum height of 1500 mm. However, the need for a pulley room may be avoided by using an underslung roping arrangement, see Figure 6.34(h).

The top of shaft loadings are approximately double that involved where the machine is positioned overhead. Upthrust loads are also applied to the lift machine.

6.2.5.3 Bottom drive: machine adjacent

The machine is positioned adjacent to the shaft at low level, see Figure 6.9(d). The drive sheave can be supported on an extended gear shaft within the lift well or a series of pulleys can be utilised to achieve the correct rope alignment to the overhead pulleys. The pulley room

arrangement is as described in section 6.2.5.2. The loadings at the top of the shaft are the same as for bottom drive with machine below.

6.3 Hydraulic drives

6.3.1 General

For certain applications hydraulic drive has many advantages over electric traction. However, misapplied, hydraulic drives can cause major problems for building, owner and user.

Low-traffic passenger, goods, vehicle and bullion lifts are all suitable applications for hydraulic drive. For applications which involve very large loads, hydraulic drive often provides the best solution because the floor of the well carries the load of the lift. Hydraulic drive, with the cylinder in a borehole, is often specified for observation lifts in commercial buildings, see section 4.3.2.

In many older buildings, not originally designed to include a lift, hydraulic lifts are often the only type suitable due to restricted building height and building structural strength.

The practical maximum travel is about 20 m. This is due to the strength and length of the hydraulic jacks. As travel increases, larger diameter pistons have to be used to resist the larger buckling forces. This increases equipment costs and makes the use of the hydraulic drive less attractive when an alternative drive is available. The contract speed is normally limited to 0.63 m/s.

Mechanical anti-creep mechanisms may be used where very heavy loads (i.e. greater than 3200 kg) are carried or fork lift trucks are moving in and out of the lift. Active relevelling systems may cause problems in these circumstances where small-wheeled trolleys are used.

Caution should be applied in considering hydraulic lifts for commercial buildings where continuous heavy traffic is expected since this may require lift speeds of 1 m/s or greater. Cooling is essential under these circumstances since 0.63 m/s is generally accepted as the maximum for hydraulic lifts without cooling. This cooling requirement is often neglected in the design of the building.

Hydraulic drives are not suitable for intensive use or for groups of lifts. Even duplex lift groups (i.e. two lifts) may exceed the recommended maximum number of motor starts per hour (i.e. 45) without additional cooling. Such cooling may be costly or impracticable. However, hydraulic drive is sometimes the only solution, even in high traffic situations, due to building structure constraints. In these circumstances, extra cooling for the drive unit and oil must be provided.

For private residential buildings of up to eight storeys, hydraulic lifts may be used due to the low traffic levels in such buildings.

Simple hydraulic drives, which do not use counterweights, have the following attributes:

- low loads imposed on the building, therefore suitable for large goods lifts
- lift machine room normally positioned in the basement, or other low-cost area of the building
- economic for low-traffic, low-rise applications with either single lift or a group of not more than two lifts
- a borehole location for the hydraulic cylinder may provide a visually attractive feature for low-rise observation lifts
- depending on the layout and number of jacks, the lift well area can be smaller than that for the equivalent electric traction lift.

Hydraulic lifts which use counterweights save energy but the major advantages of the simple hydraulic lift can be lost due to the increased loads on the building and the cost of fabricating and installing the additional mechanical components.

Pump rooms for hydraulic lifts must have adequate ventilation to prevent extremes of oil temperature (see section 9.2.3). The power dissipation of the drive into the pump room can be obtained from the lift supplier. In the event of a hydraulic fluid leak, the pump room and the lift well must be capable of retaining the hydraulic fluid used in the system by means of an oil-proof floor covering.

With all hydraulic lifts the control equipment and pump unit can be positioned remote from the lift in a more suitable area of the building.

6.3.2 Jack arrangements

6.3.2.1 Direct-acting

The jack is connected directly below the lift car, see Figure 6.10(a). A lined borehole is required to accommodate the cylinder.

A central jack is ideal for heavy loads and low rise applications. Effectively there is no limit on the car size or on the rated load capacity. The central jack arrangement makes optimum use of shaft space because there is no counterweight or hydraulic jack alongside the lift car.

The limitations of this arrangement are as follows:

- provision of a lined borehole can prove expensive
- inspection of the jack is restricted and, on rare occasions, the unit may have to be lifted out of the borehole for maintenance
- problems may be encountered with underground rock and/or water
- travel is limited to approximately 20 m by the buckling factor for the piston.

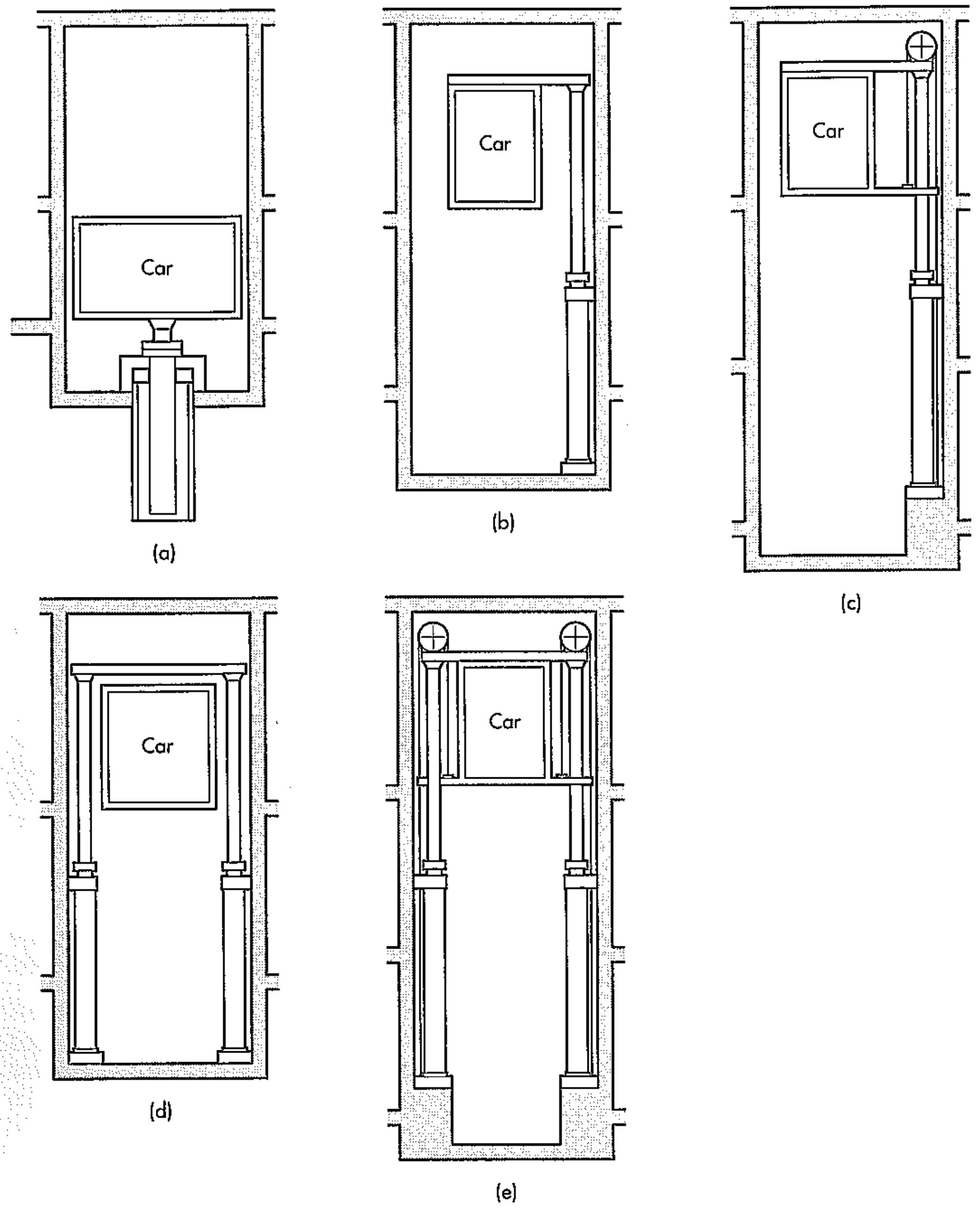

Figure 6.10 Hydraulic jack arrangements; (a) single, central, (b) single side-acting (direct), (c) single side-acting (indirect), (d) twin side-acting (direct), (e) twin side-acting (indirect)

6.3.2.2 Single side-acting

Side-acting jacks can be connected either directly or indirectly to the lift car.

With a direct side-acting jack, the jack is located within the shaft structure alongside the car, see Figure 6.10(b). In this arrangement the car applies a lateral force to the rails and structure. The cantilever loads imposed on the shaft wall (approximately 1600 kg) restrict the single side-acting arrangement to light loads only. The lift travel is limited by the piston length, usually 3.5 m.

The indirect side-acting jack arrangement is similar to the direct side-acting, except that the connection between the piston and lift car is achieved by means of a rope/chain and pulley arrangement, see Figure 6.10(c). This arrangement gives a 2:1 ratio of car travel to piston stroke. Safety gear is required with this arrangement, see section 6.11.

6.3.2.3 Twin (tandem) jacks

As with single side-acting jacks, the twin jack arrangement may be either direct or indirect acting.

The limitations of twin jacks are:

— increased shaft size

— increased installation and running costs due to the use of two rams

— load limited to approximately 20 000 kg.

In the direct-acting arrangement, a jack is positioned at either side of the lift car, see Figure 6.10(d) and this arrangement will accept heavier loads than a single side-acting jack.

The indirect-acting arrangement is similar to the direct-acting twin jack arrangement, except that the car is

connected to the jack by a rope/chain and pulley arrangement, see Figure 6.10(e), giving a 2:1 ratio of car travel to piston stroke. Safety gear is required with this arrangement, see section 6.11.

6.3.3 Power units

There are two basic types; exposed and enclosed. In both cases the components and principles of operation are the same. The main components are as follows:

— tank or oil reservoir

— pump

— pump motor

— flow control valve block.

In exposed types, these items are mounted on a frame for easy installation. However, the enclosed type is now more common in which the pump and motor are submerged in the oil tank, see Figure 6.11. The control valve may sit either inside or on top of the tank unit.

The pump unit should be located as close as possible to the base of the cylinder to avoid an excessive pressure drop between the jack and the pump unit.

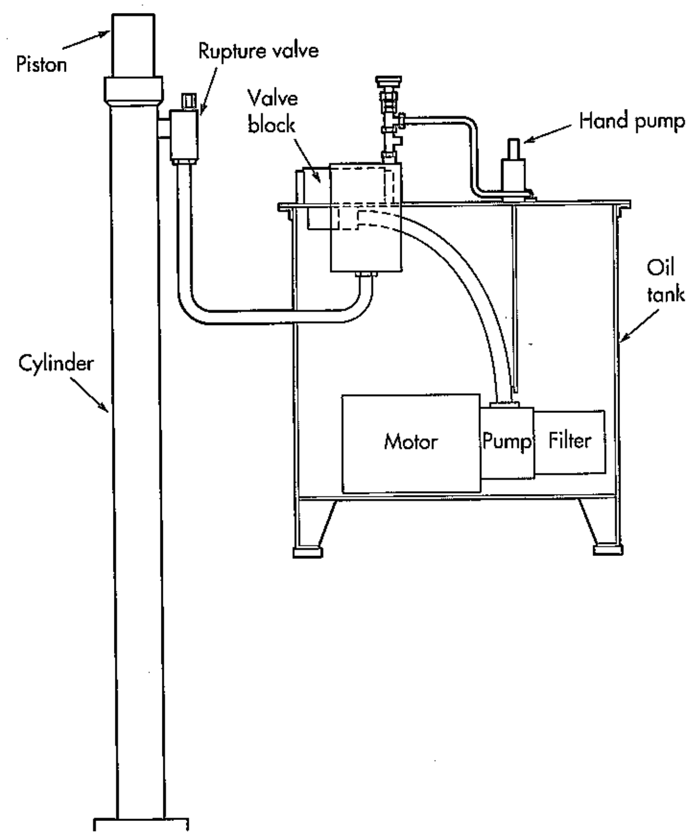

Figure 6.11 Enclosed hydraulic system

6.3.3.1 Pump motor

The most common motor is the single-speed AC induction type. It is usually flange-mounted to the pump on the enclosed versions but may be foot-mounted and belt-driven on exposed types.

In enclosed types, open-frame motors are used to ensure that the oil circulates throughout the motor to provide cooling. This has distinct cost advantages because it enables high power outputs to be obtained from relatively small motor frame sizes. However, the heat rejected by the motor heats the oil and thus causes its viscosity to change.

The motor drives the pump, of which the multi-screw type is most common since screw pumps are generally less noisy than other types.

A means must be provided within the lift controller to ensure the pump cannot be run in the wrong direction for any length of time if a fault develops. Submerged pumps use the hydraulic fluid as a lubricant and, if reversed, this lubricant will be pumped away causing the motor to seize.

Motor protection in the form of thermistors embedded in the windings is essential and an oil temperature sensor is good practice. This checks oil temperature and ensures the unit is shut down if a certain temperature is exceeded. The tank must be provided with a gauge or dipstick to determine fluid level.

6.3.3.2 Control valve

When upward movement of the lift is required oil is pumped to the flow control valve block at a constant rate. The valve block will allow either all the oil to flow to the jack or divert some back into the tank depending on the lift speed required. All valve systems currently available use this system of speed control although construction of the valve blocks vary considerably.

A silencer may be provided, either between the pump and valve block or after the valve block. These devices usually reduce noise by about 2–3 dBA. Most noise occurs when the valve block is bypassing oil to the tank and under such conditions noise levels of 80–85 dBA are common.

A shut-off valve should always be provided on the output of the valve block so that it can be isolated from the jack for servicing. A pressure gauge connection point is essential although the gauge itself may not be permanently fitted.

The complete assembly should be mounted on isolating pads. It should be installed plumb and level but absolute accuracy of alignment of the assembly is not essential. The items requiring critical alignment are generally the pump and the motor and this is usually carried out by the manufacturer at the factory.

6.3.3.3 Hydraulic jack

In a hydraulic system, power is transmitted to the lift car either directly or indirectly by a hydraulic piston or pistons, see Figure 6.10. Various names are given to this component such as jack, ram, plunger or piston. The main parts of the assembly are the cylinder, piston, seals and collar.

The cylinder is made from steel tube and may be in several sections depending on its length. The piston is made from steel ground to fine tolerances. Chromium plating provides a longer seal life and gives protection against certain environmental conditions. However, this is costly and usually not essential.

Like the cylinder, the piston may be made in several sections and various methods of jointing are used. The only criteria for jointing, apart from mechanical strength, should be the accuracy of the joints. Properly made joints should be imperceptible to the touch.

At the bottom of the piston, there should be a collar to prevent the lift from striking the building structure in the event of overtravel and to prevent the piston from leaving the cylinder. The top of the cylinder (or the top of each section in the case of telescopic jacks) should have a gland or seal to retain the oil. This gland should seal by the force of the oil acting upon it rather than by being crushed by its retaining plate. When working properly the piston should be covered by a very thin film of oil; anything more than a film indicates a problem. A scraper ring protects the seals from damage by abrasive particles, and the foils guide the piston through the seals.

The most common problem associated with jacks is premature failure of the seals. This can be caused by long-term storage in a horizontal position, defective scraper ring or impurities in the oil, misalignment of the cylinder, incorrectly installed seals or piston joints of poor quality. Dressing of joints is something that should be done with great care and only if essential.

After manufacture the assembly should be pressure tested to comply with *BS 5655: Part 2*[5] or other codes as specified.

The piston must satisfy the buckling factor and other requirements stated in *BS 5655: Part 2*. Obviously the higher the lift travel, the stronger and heavier the piston will become and this may require solid piston sections. For this and other reasons, hydraulic systems are not normally considered practicable for heights greater than 20 m.

The actual piston length depends on travel distance of the lift and the system employed. For direct-acting systems, the length is approximately equal to the travel plus the top and bottom overtravel, see Figure 6.12(a). For indirect-acting systems, the piston length is approximately equal to half of the sum of the travel and the total (i.e. top and bottom) overtravel, see Figure 6.12(b).

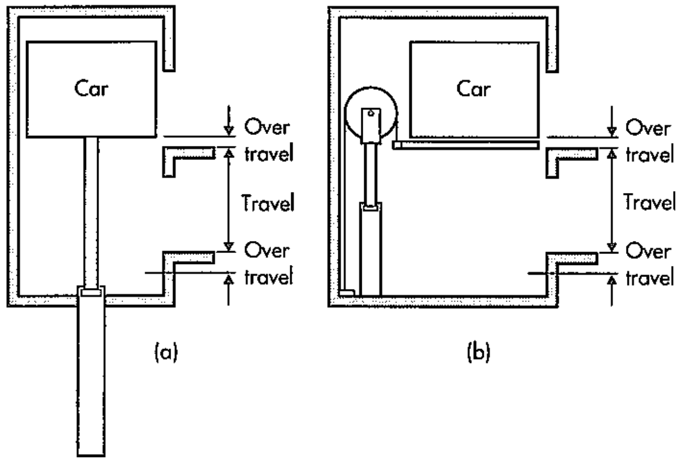

Figure 6.12 Overtravel; (a) direct-acting arrangement, (b) indirect-acting arrangement

The assembly is manufactured and installed to ensure that, when in the fully extended position and against its collar, the car does not strike any part of the structure. When the lift is at the bottom, fully compressing its buffers, the piston should not be touching the bottom of the cylinder. These conditions should be checked as part of the lift testing procedure.

Cylinders and pistons cannot easily be altered in length. Therefore, it is essential to ensure that the jack assembly is manufactured accurately and it is vital to ensure that the lift travel is not altered by the builder or architect without first consulting the supplier. Very little tolerance is provided and a variation of travel of as little as 20 mm can have serious consequences. (Note that the tolerances on the building dimensions may be considerably greater than the tolerance on the piston stroke.)

With indirect-acting arrangements the travel is still critical, see Figure 6.12(b), as is the pit depth. No variations must be made, however small, without first consulting the supplier.

Whichever system is provided, the piston and cylinder assembly must stand perfectly plumb and be securely fixed.

6.4 Controller cabinet

The controller cabinet contains the equipment necessary to control and monitor the operation of the lift installation. The control systems themselves are considered in section 7.

Controller cabinets vary in size according to the complexity of the installation. Typical heights range from 0.5 to 2.5 m. They should be securely fixed, square and plumb, to the machine room wall or floor and in such a position as to ensure easy access for maintenance. Adequate lighting must be provided.

Ambient environmental conditions must be maintained as specified by the controls manufacturer, see sections 7 and 9. In some cases it may be necessary to provide coolers on the cabinet to reject the heat generated into the machine room, see section 9, Figure 9.1.

6.5 Guide rails

6.5.1 General

Some form of guide rails are required for the car and counterweight (where provided) to ensure travel in a uniform vertical direction. The position and alignment of the guides is very important and, with the exception of the drive, no other component has such a significant effect on the ride quality.

Although round and other sections have been used, T-section rail is now used almost exclusively.

6.5.2 Position of rails

The relative position of the guide rails depends upon such factors as location of the entrance, shape of the car and centre of gravity of the car. The actual location will have been determined during the design stage and lift manufacturers will advise on what is and what is not possible.

Guide rails should be kept as near to the centre of gravity of the car as possible. A cantilevered arrangement may be acceptable at speeds up to 1 m/s but ride quality will be difficult to maintain as speed is increased beyond this level.

Where possible, the guide rails are located either side of the car, see Figure 6.13. The number of guide rails depends upon the loads to be handled and the sizes available for use. Two rails for the car and two for the counterweight is the most common arrangement but there is no real limit on the number that can be used. The guides are drawn from steel and the running blade is usually machined to a finish, though not in all cases.

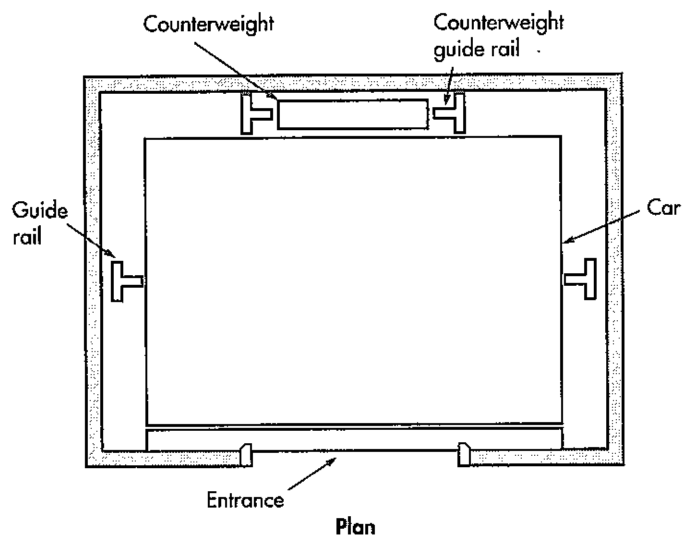

Figure 6.13 Position of guide rails

6.5.3 Size of rails

The size of the rail selected will depend on the forces that it is required to withstand. During lift travel, the forces will be comparatively low, especially if the car is well balanced and the load is well distributed. During loading of the car, however, large loads may be exerted upon the rails. This is especially true of goods lifts being loaded using fork-lift trucks. These loads will produce a twisting moment in the rails. Under extreme conditions, it may be necessary to provide a means of locking the lift to the structure to relieve the rails of some of this load.

The other loads exerted on the rails will be from application of the safety gear under emergency conditions. This will result in a large compressive load being transmitted to the rails as well as a bending stress. The means of calculating these forces, and thereby selecting rail size, is laid down in *BS 5655: Part 9*[6].

6.5.4 Alignment of rails

The need for accuracy in the installation of the rails cannot be overemphasised, especially for lift speeds of 2.5 m/s and above. At speeds greater than 4 m/s, rail alignment becomes critical. Manufacturers of rails usually

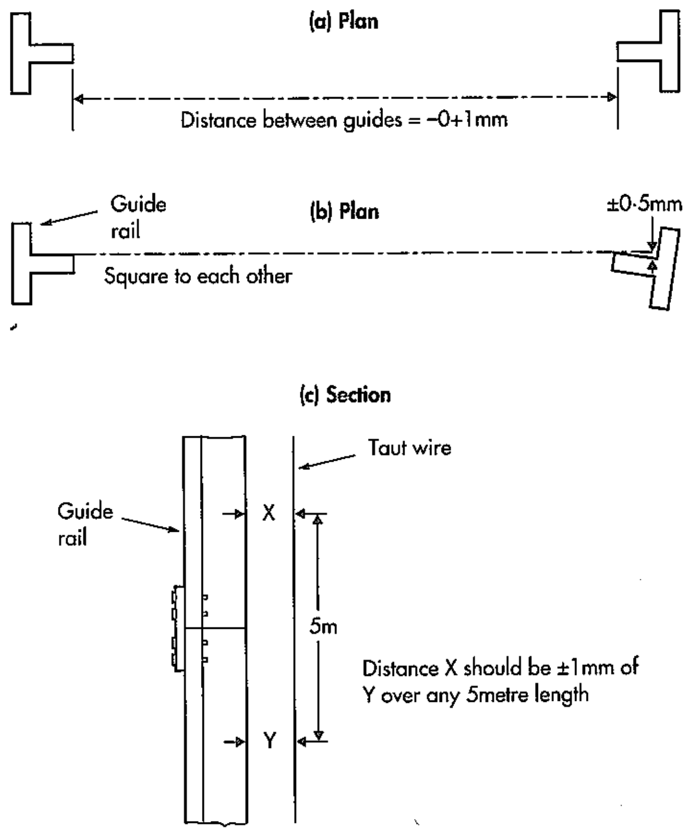

Figure 6.14 Alignment of rails; (a) tolerance on distance between guides, (b) tolerance on accuracy of angular alignment, (c) tolerance on vertical alignment

offer two grades of finish: first grade being recommended for speeds greater than 2.5 m/s.

It is very difficult, if not impossible, to align rails correctly once the lift car is in the shaft. They should therefore be checked before the car is installed so that any error may be corrected. It is also common practice to use the rails as working centres for all dimensions. Therefore if these are wrongly aligned almost everything else will be wrong.

Figure 6.14 provides a guide to installed accuracy. It is often not appreciated that the accuracy of alignment of the rails for the counterweight is as important as the alignment of the car rails.

6.5.5 Rail fixings

Guide bracket and clip design is important as these items provide the means of holding the rails in alignment.

For low-rise installations, forged steel clips may be used to hold the rails rigid. For installations higher than 20 m, spring clips are favoured because they allow for building compression. All buildings expand, contract and move to some degree and rail alignment obtained during initial installation should be maintained while this occurs. Again the higher the building and the faster the lift, the more critical this aspect becomes.

At speeds up to 2.5 m/s, it is good practice to clean the back of rails and face of brackets and to apply a small amount of grease to facilitate movement. At 2.5 m/s and above, most manufacturers provide more sophisticated arrangements to enable movement to occur, e.g. by employing brass shims between the brackets and the back of the rail.

6.5.6 Length of rails

While the guides must be long enough to ensure that the car and counterweight never leave the rails during overtravel, clearance must be left between the top of the rails and the structure. This is to ensure that when the building compresses it does not compress the rails. The dimension is approximately 3 mm for every 3.5 m of travel. For travel above 100 m the structural engineer should be consulted regarding the anticipated compression distances. In the absence of specific data, 5 mm per 3.5 m of travel should be allowed.

6.6 Counterweight

6.6.1 General

The counterweight provides traction between the ropes and sheave, balancing the weight of the car and a proportion (normally 40–50%) of the load to be carried. Counterweights usually consist of a steel frame of welded or bolted construction, see Figure 6.15.

The mass of the counterweight is made up of small weights, known as filler weights, made from steel, cast iron or concrete. The material selected is not critical provided its weight stays constant with age and atmospheric changes and does not burn. Some additional weights, known as make weights, may be used for precise balancing. These weights are clamped into place in the frame with clips, rods or plates so that they cannot fall out. Wood or other blocks may be provided underneath the weight for taking up rope stretch.

Sliding or roller guide shoes at the top and bottom of the counterweight guide it smoothly along the rails.

The frame should be constructed to avoid undue distortion and should hang reasonably central of the rails of its own accord. This ensures that the shoes are subjected to minimum force and therefore minimum wear. This is particularly important for counterweights employing roller guide shoes: if the counterweight is forced into place by undue roller pressure the rollers will develop flats that will result in noise and vibration.

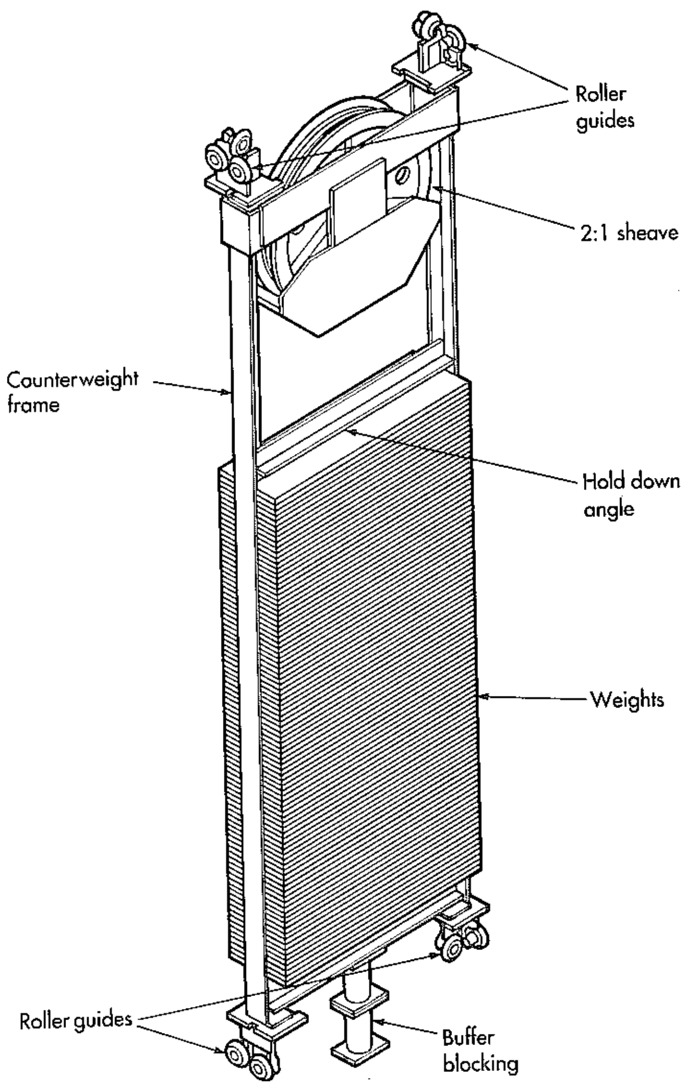

Figure 6.15 Typical counterweight

Counterweights with rollers should, therefore, be statically balanced in the same way as lift cars with roller guide shoes. This involves arranging the filler and make-weights, along with the rope hitch-point, into such a position that the counterweight hangs centrally within the rails without the use of the rollers. The rollers are then adjusted to provide minimal pressure on the guide blade.

In addition to checking the overbalance and roller or shoe adjustments, the main considerations during installation of the counterweight are to ensure that it does not strike the building structure when the car is fully buffered and to check that the safety gear, if provided, is operating.

6.6.2 Counterweight sheave

A sheave or sheaves may be provided on the counterweight, depending on the rope arrangement employed. When provided, rope 'kick-off' guards should also be included to prevent ropes leaving the sheave during sudden stopping, or if some foreign object should become lodged between the ropes and sheave.

6.6.3 Counterweight safety gear

Safety gear (see section 6.11) must be provided if the counterweight is running above a passage or area accessible to persons. This generally means that the size of the guide rail must be increased to take account of the load the gear applies to the rails during application.

On a low-speed unit, the safety gear may be operated by failure of the main ropes (e.g. a broken rope). On units running at 1 m/s or faster, governor actuated gear is required. With speeds of up to 1 m/s the safety gear may be of the instantaneous type, but progressive types should be used above this speed.

6.6.4 Compensation

The counterweight may also carry compensation ropes, see section 6.14.2. If tied-down compensation is used the counterweight will be subjected to considerable stress when the car safety gear is applied, over and above the usual stress for which it is designed, such as striking the buffers at full speed.

6.7 Lift car

6.7.1 General

Most lift cars today consist of two distinct assemblies: the sling or car frame and the car itself.

The sling is a steel frame of welded or bolted construction which provides a cradle in which the car can sit. It has to be of sufficient strength to withstand the stresses applied to it when the car is accelerated and the compressive forces resulting from a fully laden car striking the buffers at speed or when the safety gear is actuated.

Safety gear should always be provided if the car is for passenger use, or is of a size that a person can enter for the purpose of unloading even if it is not primarily for passenger use (see also section 6.11). The requirements for the provision of a safety gear are defined in *BS 5655: Part 1*[1] for electric traction lifts and *BS 5655: Part 2*[5] for hydraulic lifts.

The safety gear will usually be located under the car frame but may be at the top or halfway up. The position is not important provided that the gear is fixed securely to the frame.

6.7.2 Car frame

The main parts of the frame are the crosshead or crown bar, the uprights or side posts, and the bottom channels or plank channels, see Figure 6.16. Many styles and variations exist and on very large lifts more than one sling may be bolted together to provide the support the car requires.

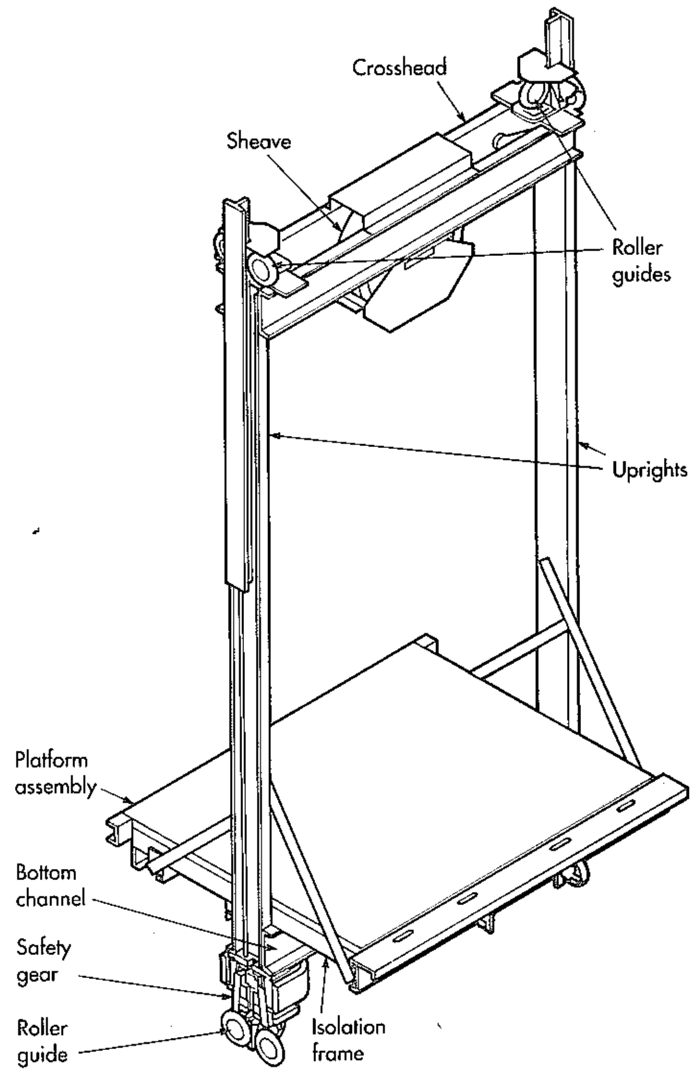

Figure 6.16 Typical car frame

Shoes or rollers are provided at each of the four corners of the frame to guide it along the rails. Ropes may be attached directly to the frame or pass around sheaves placed above or below it.

The construction of the sling is important not just in terms of strength but of alignment It should be assembled free of distortion, especially if roller guide shoes are to be used. Once built, distortions are difficult, but not impossible, to remove.

6.7.3 Platform/enclosure assembly

Passenger lifts will usually have an isolation frame attached to the car fame, see Figure 6.16. The purpose of the isolation frame is to separate the passenger compartment from vibrations present in the car frame during running. The platform is supported by rubber pads fixed to the isolation frame. The platform should be levelled front to back and side to side before the walls are attached. The isolation pads compress under load and can therefore be used to provide information on the load in the car.

For passenger lifts, the platform is usually made of steel and may have a timber overlay to reduce noise. If factory-assembled, the walls would then be installed, along with the car front, and finally the roof would be added. If assembly takes place on site, however, it may be necessary to install the roof and hang it temporarily from the crosshead while the walls are installed. The roof is often in one piece and therefore must be installed before the walls are in place.

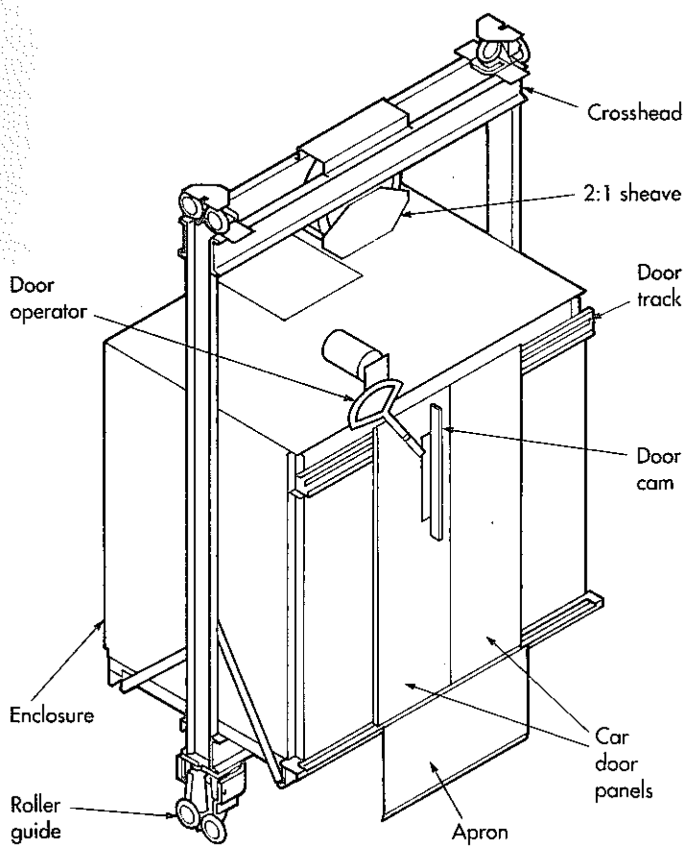

Figure 6.17 Construction of typical passenger lift car

Whichever method is used, the walls must be plumb and square without being forced into position. If not, the car will quickly develop squeaks and rattles. Walls should not deflect beyond the limits indicated in *BS 5655: Part 1*(1). The roof when installed should be able to support the weight of two persons without permanent deformation (see also *BS 5655: Part 1*). The forces exerted on the platform during passenger transfer are not large and should be based upon the requirements of *BS 5655: Part 1*.

The top of the car is held to the frame by isolated steady devices so that at no point is it mechanically bolted to the car frame. Figure 6.17 shows a typical passenger lift car with the car shell constructed and the door tracks, cill and doors assembled.

For goods lifts, the platform isolation and resilient steady devices are normally omitted because it is important to hold the platform securely to withstand the forces applied during loading. For lifts intended to carry general goods, it is assumed that not more than 30% of the load can be placed in the car in a single operation. If the car is to be loaded using trucks (either hand or power operated), this intention must be made clear to the lift supplier since the combined weight of the truck and its load may exceed the maximum load for which the lift is designed.

6.8 Door operators

6.8.1 General

The function of the door operator, or door engine, is to open and close the doors in a safe and swift manner.

Various methods are used to drive lift doors but the most common is an electric door operator mounted on top of the car, see Figure 6.18. When the lift approaches or

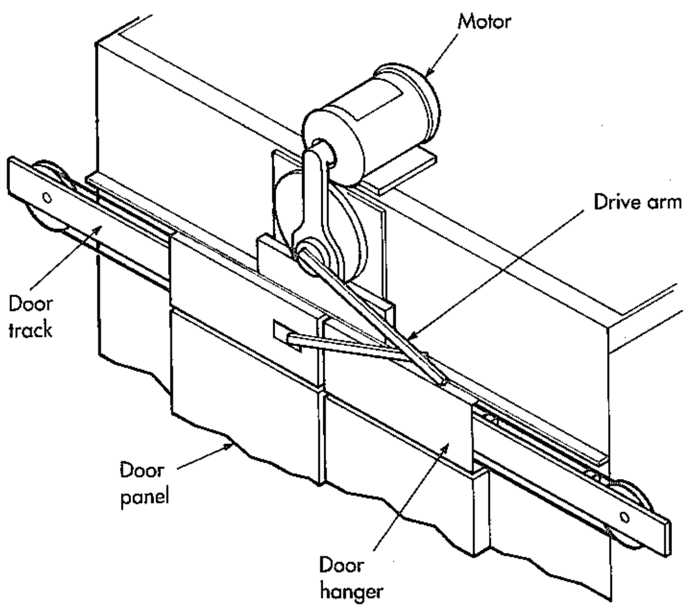

Figure 6.18 Typical door operator

arrives at a floor, a mechanical device couples the car doors to the landing doors. As the car doors open they also pull open the landing doors.

This method has two distinct advantages. First, only one door operator is required for each car entrance regardless of the number of landing doors on that side of the car. Secondly, the landing doors cannot be opened if the car is not at a floor.

The disadvantage of this arrangement is that the operator may have to open and close doors of different weights. For example, the main lobby may have heavy bronze doors while the doors on all the other floors may be of light panel construction. Under such circumstances the design of the operator must be a compromise; sufficiently powerful to open the lobby doors in a reasonable time but not so powerful that the doors on other floors are opened too fast since this may prevent smooth operation of the doors at all floors.

6.8.2 Principles of operation

To open the doors, the operator must accelerate the door from zero to full speed and back to zero in a smooth, quiet manner. This is usually achieved by a mechanical linkage which converts the rotational movement of the motor into a sinusoidal or harmonic door movement. The faster this operation the better because it saves time in loading and unloading. To open the doors smoothly at high speed requires good speed control; therefore high-speed door operators are generally more expensive than low-speed types.

Closing the doors raises different problems. While it may be desirable to save time by closing the doors quickly, *BS 5655: Part 1*(1) sets limits on the maximum kinetic energy imparted to closing doors to reduce the risk of injury to passengers. The current figure is 10 J provided that a safety device, such as a passenger detector, is in operation (see section 6.8.6). This limit applies at the average speed of the doors. In addition, the force necessary to prevent the doors closing must not exceed 150 N. If no safety device is provided, or an existing safety device is not operating, the maximum kinetic energy permitted is 4 J.

The most difficult control function, and the most mechanically severe, is the reversal of the direction of motion of the door while closing at high speed. Under such conditions the doors must be rapidly decelerated, stopped and then accelerated in the opposite direction. Poor design or incorrect adjustment of the system will result in premature failure of the drive and its bearings, a common fault with door systems. Bearing and drive failure may also be caused by adding too much weight to the doors, for example by applying a heavy finish to existing doors. The type of door should not be changed unless the capabilities of the door operator are known to be adequate to accommodate the extra weight.

Although initially more expensive than the simple sinusoidal operator, the principle of linear motion, whereby the door movement is linearly proportional to the motor rotation, provides better control of the door movement. With linear door operators, interruption of door closing does not generate such high mechanical forces and this ensures long-term quietness in operation.

6.8.3 Door operator motors

The operator itself may use:

- a DC motor driving through gears or a mechanical linkage system
- an uncontrolled AC motor driving through a gearbox
- an AC or DC motor with closed-loop speed control.

In the case of AC motors, variable frequency control may also be used. Control of door operators is dealt with in section 7.5. The motors are usually designed for the function and, depending on the manufacturer, may be suitable for continuous stalled operation thereby eliminating the need for stall protection.

Until the 1980s, only DC door operators provided a means of adjusting the door speeds and therefore these were used for lifts with higher door speeds and wider entrances. AC operators, without any speed control, were restricted to smaller lift car entrances and had fixed opening and closing times. Several manufacturers now produce electronically controlled AC and DC door operators suitable for higher door speeds. Some of these use position and velocity control along with sophisticated passenger detection and logic control.

Single-speed AC door operators are most suited for entrances up to 800 mm wide where there is a low density of traffic. In other situations, lift efficiency and passenger comfort are improved by the use of DC and controlled AC operators.

DC door operators provide good all-round performance for most applications. The operating times can be adjusted to suit user requirements for comfort. It is difficult, however, to modify the speed of the doors in response to varying traffic conditions. Nudging, to close the doors slowly when obstructed or held open unnecessarily, is easily accomplished.

6.8.4 Door operating times

The selection of a suitable door operator usually depends upon the application. Generally, high-speed door operators should be used with high-speed lifts. There is little point in having a fast ride if this is followed by slow, noisy door operation.

Table 6.1 shows typical door opening and closing times and likely applications for door operators. The terms low, medium and high speed are not well defined and therefore the figures are given only as a guide. Note that low-speed operators are generally of low cost and usually cannot provide faster opening than closing.

Table 6.1 Door operating times

Operator	Door type	Opening size† (mm)	Opening time (s)	Closing time (s)
Low speed	Two-speed	800	4.8	4.8
		900	5.1	5.1
	Centre-opening	800	4.1	4.1
		900	4.7	4.7
Medium speed	Two-speed	800	2.9	3.3
		900	3.1	3.5
		1000	3.3	3.7
		1100	3.5	4.2
	Centre-opening	800	2.3	2.5
		900	2.4	2.6
		1000	2.5	2.7
		1100	2.7	3.3
High speed	Two-speed	800	1.8	2.8
		900	1.9	3.4
		1000	2.0	3.6
		1100	2.2	3.4
	Centre-opening	800	1.5	2.0
		900	1.6	2.2
		1000	1.7	2.5
		1100	1.8	2.9

† Door height taken as 2100 mm in all cases

For a given width, centre-opening doors will have shorter opening and closing times than side-opening doors.

The opening and closing times of the doors have a significant effect on the lift efficiency and cycle time: a one second saving on door operation gives approximately 5% greater traffic handling capability.

6.8.5 Installation

With power-operated doors, the operator should be installed to the manufacturer's recommendations. It may bolt directly to the car roof, with or without isolation, or it may be fixed to its own support frame which is, in turn, bolted to the car frame.

Following installation of the door operator, it should be checked thoroughly for smooth, quiet operation. Doors and operators account for some 80% of breakdowns on lift systems.

Manufacturers should state opening and closing times, as well as noise levels, and these should be checked after installation. The kinetic energy of the doors when in motion should also be checked, see section 6.8.2.

6.8.6 Door safety devices

Passenger detection devices are necessary for the safety and comfort of lift users and to provide controller inputs for the operation of the doors and the lift drive. The time taken to react to an obstruction varies with the type of detector and several different times may be used.

A mechanical safety edge can be mounted on the leading edge of the car door. The safety edge moves when it strikes an object and this movement causes the doors to reverse direction. While simple to construct and reassuring to passengers, mechanical safety edges are easily damaged by trolleys etc.

More common are electronic safety edges in which a solid-state detector is located on or beside the leading edge of the car doors. This produces a detection field that may extend for a short distance (say, 100 mm) in front of the door, or it may cover the whole opening width. When the field is interrupted the door reverses direction. This type of system has the advantage of reversing the door before it hits the obstruction. For this reason, electronic safety edges are preferred to mechanical types. Modern electronic edges are robust and stable, and their ability to sense obstructions without contact is more comfortable for passengers and provides better protection for the doors. In the event of failure of the detector, the doors should stay open or be permitted to close only at slow speed (nudging operation) with a warning buzzer sounding.

Figure 6.19 shows a typical mechanical safety edge and passenger detector systems and Figure 6.20 shows a wide-field electronic safety edge.

Photocell detectors provide remote sensing across the complete door entrance. They can be a useful addition inside the car, either on the door returns or built into the detector edge, but they should be provided in addition to a safety edge or detector, not as an alternative. For goods lifts, a photocell detector built into the landing architrave is a good way of protecting the landing doors. Despite the claims made by manufacturers, most car door detectors provide only partial protection to the landing doors.

A photocell detector can allow more efficient use of the lift, by acting as a 'door open' (dwell time) monitor. These devices modify the dwell time in response to passengers moving through the entrance. If an obstruction is present, door closure is delayed to prevent unnecessary reopening caused by safety edge operation.

Optical passenger (obstruction) detectors provide even greater door protection in situations where heavy objects have to be moved through the entrance. Again, these detectors should be used in addition to safety edges. Optical passenger detectors use simple video cameras with local image processing to detect passengers and objects approaching the lift entrance. Situated above the car doors, the landing doors or between the car and landing doors, the field of view can be angled to meet the requirements of the application. Typical situations where these devices have proved advantageous are in airport terminals and hospitals. They can, however, interfere with normal service if located above the landing doors by detecting persons passing the lift rather than those waiting to use it. The field of view must be carefully adjusted to avoid false sensing.

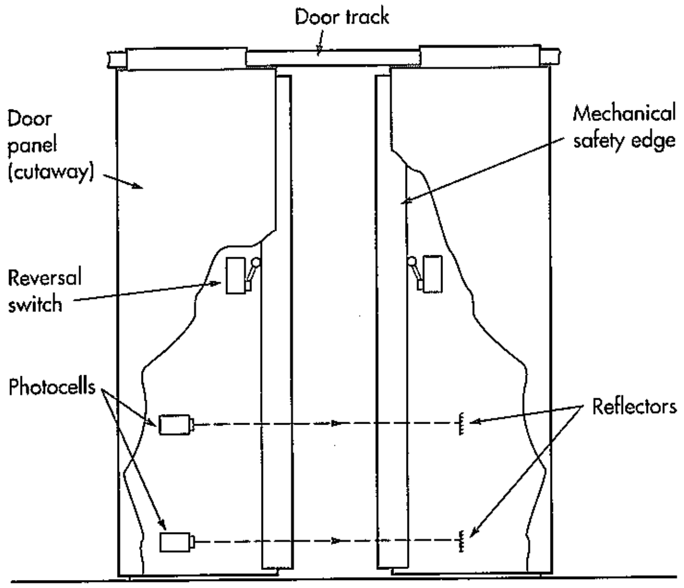

Figure 6.19 Schematic of typical mechanical safety edge

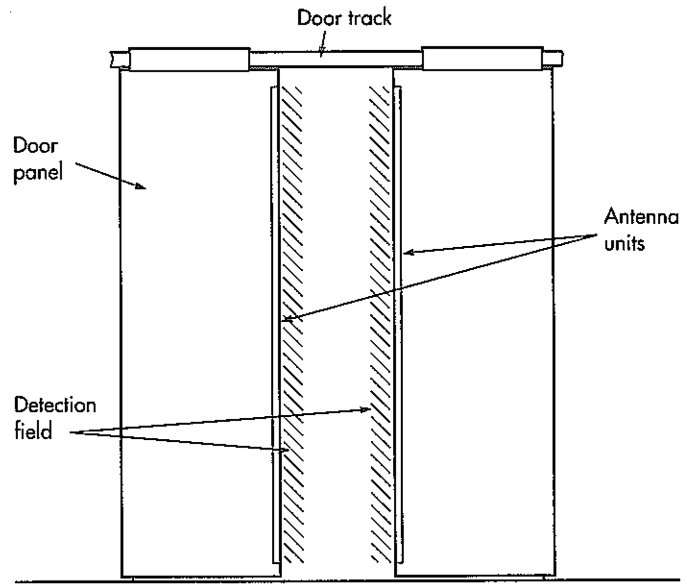

Figure 6.20 Schematic of typical electronic passenger detector

6.9 Door configurations

6.9.1 General

While various types of door exist, all serve the same prime function: to prevent persons or objects from entering the path of the lift. Each type, however, offers certain features or advantages.

The mechanical strength required for doors and their locking mechanism is laid down in *BS 5655: Part 1*[(1)]. The completed panel assembly should be designed to be as free running as possible, with all clearances within the limits laid down by *BS 5655: Part 1*.

The face of sliding doors should always be kept as flush as possible. While the standard permits recesses and projections up to 3 mm in the face of the door, these should be avoided if possible. Safety must always be the prime consideration.

6.9.2 Single-hinged, manual doors

The simplest, and generally the least expensive, type of landing door is the single-hinged, see Figure 6.21.

In the past, these were frequently made from wood but, because of its flammability and its tendency to warp, steel doors are now more common. Single-hinged doors require very little space in terms of width since they consist of only the door and a simple frame. The disadvantage is that they usually open out to a right angle with the wall and therefore obstruct corridors. They are difficult to open for persons in wheelchairs or the elderly or disabled. They are, however, acceptable for simple, low-cost passenger lifts serving a small number of floors. Typical opening widths for these doors are 700, 800 and 900 mm.

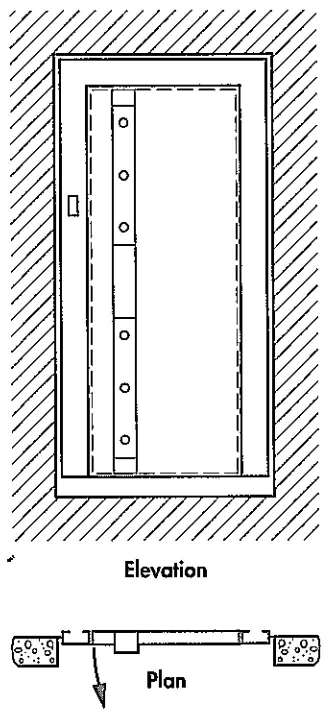

Figure 6.21 Single hinged door

6.9.3 Horizontal power-operated sliding doors

The most frequently used power-operated door for passenger lifts are horizontal sliding doors, see Figure 6.22.

The simplest of these is the single-slide version, see Figure 6.22(a). The single panel is pulled open or shut by the car door operator. As only one panel is used the construction is simple and reliable but requires a greater shaft width in many instances for a given opening, i.e. approximately twice the opening width plus 300 mm. The typical opening width is 840 mm. These types of doors were commonly used for lifts in local authority housing during the 1960s and 1970s. They are still used for some applications but less frequently.

6.9.4 Two-speed, power-operated doors

Two-speed side-opening door may be used where space is at a premium but powered doors are required, see Figure 6.22(b). These doors are referred to as two-speed because while both panels close simultaneously, the leading panel travels at twice the speed of the trailing panel. This means that, although the leading panel has twice the distance to travel of the trailing panel, they cover the distance in the same time. The space required by these doors is approximately 1.5 times the opening width plus 400 mm. Opening sizes for these doors are generally between 600 and 1300 mm, the most common sizes being 700, 800, 900, 1100 and 1300 mm.

6.9.5 Centre-opening, power-operated doors

The most common entrance for passenger lifts is the single-speed centre-opening door, see Figure 6.22(c). This arrangement is mechanically relatively simple, is visually attractive and is fast in operation because both panels move simultaneously, either away from or toward each other. For a panel speed during opening of 0.3 m/s, an opening of 900 mm may be created in approximately 1.6 s, whereas a two-speed door would require approximately 3 s. This time saving can be critical on large installations and groups of lifts. The space required by the doors is more

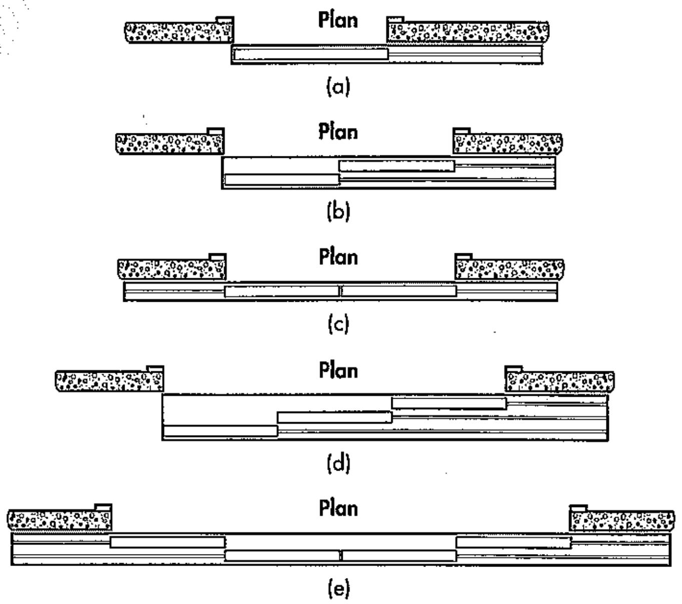

Figure 6.22 Horizontal power-operated sliding doors; (a) single slide, (b) two-speed side-opening, (c) single-speed centre-opening, (d) three-speed side-opening, (e) two-speed centre-opening

than other types being approximately twice the opening width plus 200 mm. However, centre-opening doors are preferred to side-opening where the depth of the shaft is limited.

Opening sizes for these doors are usually between 800 and 1300 mm; larger sizes are possible but generally unacceptable because of the space required. The most common door opening widths are 800, 900, 1100 and 1300 mm.

6.9.6 Wide entrance doors

For special applications, such as very large passenger or goods lifts, other horizontal doors are available. For example, two-speed centre-opening or three-speed side-opening doors are suitable for opening widths from 1200 to 2500 mm or greater, see Figure 6.22(d) and (e). However, these arrangements are generally costly and noisy because of the complexity of mechanical linkages.

6.9.7 Multi-leaf gates

For goods lifts, the requirements are generally different. Adequate space to enter the lift and within the shaft, combined with rugged, reliable operation are more important than speed of operation.

Where cost and space are at a premium, manually operated shutter gates may be used, see Figure 6.23. These are simple and rugged. The space required is the opening width plus the bunching width. The space required for bunching will vary according to the widths of opening and leaf size used.

6.9.8 Vertical bi-parting doors

For very large goods lifts, where loading will be by powered truck, vertical bi-parting doors may be used, see Figure 6.24. These may be either manual or power operated. Space requirements vary between different manufacturers. The powered versions usually have an operator motor per entrance (i.e. on each floor served). This enables each entrance to be individually operated.

The two panels that form the door counterbalance each other. As the bottom panel moves down the upper panel moves up. When fully open, the top edge of the bottom panel forms a trucking cill. The doors are designed to accept different trucking loads and the intended load should be specified.

Although opening may be fully automatic, closing is usually performed by constant-pressure button operation. The door closing sequence may be interrupted if necessary by releasing the door close button. Fully automatic power closing of these types of doors is not recommended by *BS 5655: Part 7*[7].

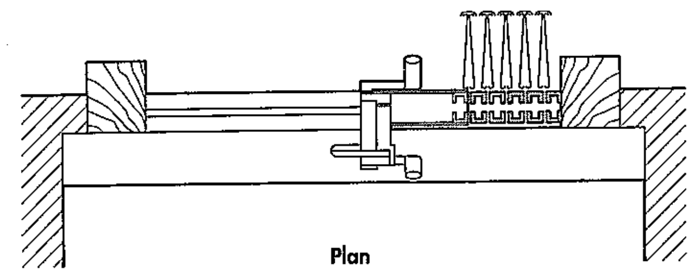

Figure 6.23 Multi-leaf gate

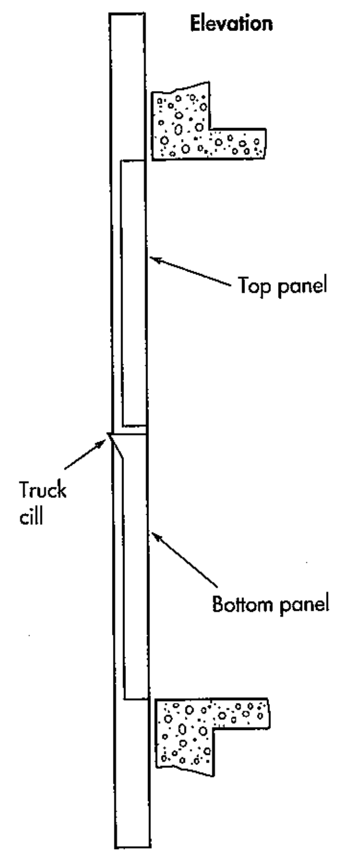

Figure 6.24 Vertical bi-parting door

6.9.9 Materials and finishes

BS 5655: Part 1[1] sets limits on the closing force and kinetic energy of moving doors (see section 6.8.2), and these may have a bearing on the materials selected for the door. Most doors are made from steel with either a painted or applied skin finish. While the finish is a matter of design choice, certain factors should be considered. For example, if heavy materials are used, door speed will have to be reduced to keep within the requirements of *BS 5655: Part 1*. Some materials, especially those with heavy embossed patterns, may be difficult to form and will therefore increase costs. Finally, heavy materials may require that the door tracks, rollers, bearings and driving operators are all increased in size to handle the extra weight.

6.9.10 Fire rating

Lift doors are often required to be fire rated. In the UK, testing of this property is laid down in *BS 476: Part 22*[8]. Unlike other fire doors, lift doors are tested to stop fire from one side only, i.e. the landing, and the ability to stop fire from the lift shaft is not a requirement. Doors are tested within their frames which are then built into a typical structure. The certification obtained will be for a given duration, typically 30, 60, 90 or 120 minutes, and will cover both integrity and stability. Insulation properties are not covered.

It should be noted that the addition of a skin may render the certificate invalid if flammable materials are used. This should be borne in mind during the selection of finishes and adhesives for fixing skins.

6.10 Overspeed governors

6.10.1 General

Overspeed governors have been used on lifts almost since the first lifts were installed. The purpose of the overspeed governor is to stop and hold the governor rope with a predetermined force in the event of the descending car or counterweight exceeding a specified speed. The rope may be held by traction forces developed between the governor sheave and its groove or by a special rope-clamping device designed to hold the rope without damaging it. The force exerted on the rope must be at least 300 N or twice the force necessary to engage the safety gear, whichever is greater.

For governors using rope traction to obtain this force, the force must be calculated in accordance with *BS 5655: Part 1*[1].

Many modern governors are now type tested and *BS 5655: Part 10*[9] sets down the requirement for on-site testing at completion of installation. The general requirements for governors are laid down in *BS 5655: Part 1*.

In the past, vertical shaft flyball governors were common but, although many still exist, their use is becoming less frequent. Horizontal shaft governors are now preferred, see Figure 6.25.

The centrifugal governor consists of a sheave, flyweights and a rope clamping device, see Figure 6.26. As the sheave rotates, the pivoted flyweights move outwards due to centrifugal force. At a predetermined speed, the weights strike a release mechanism that causes the rope-clamping device to grip the governor rope.

The rope-clamping device is designed to allow the rope to slip through its jaws if the load on the rope is too great. This ensures that the safety gear stops and holds the car rather than the governor.

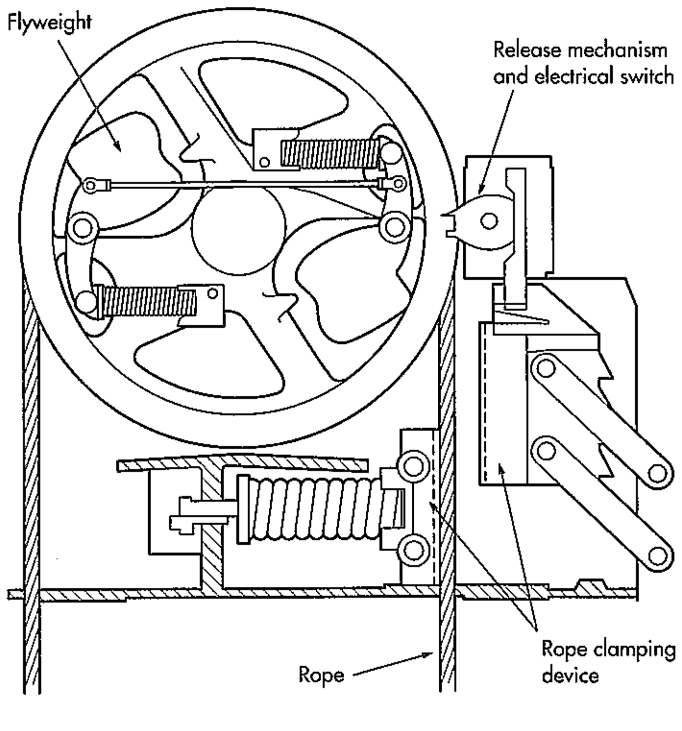

Figure 6.25 Centrifugal governor

6.10.2 Governor activation

BS 5655: Part 1[1] requires that tripping of the overspeed governor for the car safety gear shall occur at a speed at least equal to 115% of the rated speed and less than:

- 0.8 m/s for instantaneous safety gears except for the captive roller type
- 1 m/s for safety gears of the captive roller type
- 1.5 m/s for instantaneous safety gears with buffered effect and for progressive safety gear used for rated speeds not exceeding 1 m/s
- $(1.25v + 0.25/v)$ for progressive safety gear for rated speeds not exceeding 1.0 m/s (where v is the rated speed).

A governor used to operate counterweight safety gear shall be set to activate the safety gear at a speed not more than 10% greater than the speed at which the car safety gear is activated.

Governors are provided with an electrical switch that removes power from the lift motor and applies the brake before the safety gear is activated. However, if the rated speed of the lift is 1 m/s or less, this switch may trip simultaneously with the safety gear. For speeds above 1 m/s the switch is set to operate at approximately 115% of contract speed.

6.10.3 Resetting governor

After operation, the governor will either be reset by raising the car or it may require to be reset manually. The rope-gripping device should always be inspected for signs of wear after an application.

6.11 Safety gear

6.11.1 General

Safety gear is the term given to a mechanical clamping device located on the car, the prime function of which is to grip the guide rails to prevent the uncontrolled descent of the car if the lifting ropes were to part.

Any lift car designed for transporting passengers, or into which persons may enter to load or unload goods, and that is suspended by ropes requires the provision of safety gear. Safety gear may also be fitted to the counterweight, see section 6.6.3. Figure 6.26 shows a typical car frame with progressive gear located at the base of the uprights.

All types of safety gear should be applied mechanically and not rely on the operation of electrical circuits. Activating devices for safety gear are considered in section 6.11.6.

6.11.2 Instantaneous safety gear

This is the simplest type of safety gear, see Figure 6.27. It is almost instantaneous in operation but limited to lifts with speeds of not more than 0.63 m/s. This is because the small stopping distance results in heavy shock and strain, not only to the lift equipment but also to the passengers.

When fitted to a counterweight frame, the device may be used at speeds up to 1 m/s. Although the counterweight may be stopped instantly the car will come to rest under the action of gravity.

6.11.3 Instantaneous safety gear with buffered effect

Instantaneous safety gear with buffered effect may be used on cars with speeds up to 1 m/s. The safety gear again applies a rapidly increasing pressure on the guide rails but oil-filled buffers, interposed between the lower members of the car frame and the safety plank, dissipate the energy and reduce the shock to passengers.

6.11.4 Progressive safety gear

For speeds in excess of 1 m/s, progressive safety gear must be used. This device clamps the guide rails by applying a limited pressure which brings the car progressively to a standstill, see Figure 6.28. These devices are also used where several safety gears are fitted to the car as is the case with some large goods lifts. Progressive safety gear may be used at speeds below 1 m/s, if required.

The gear is designed so that under free fall conditions the retardation rate lies between 0.2 g and 1.0 g. The actual distance taken to stop the lift depends upon its speed. Requirements for stopping distances and methods of testing are given in *BS 5655: Part 10*[9].

6.11.5 Resetting safety gear

All modern types of safety gear are reset after application by upward movement of the car. This requires the intervention of a competent person not only to release the safety gear and check its condition after operation but also to determine the reason for its operation.

6.11.6 Activating devices

The most common arrangement for activation of a safety gear is by way of an overspeed governor, see section 6.10. The linkage mechanism that operates the safety gear is connected to a steel rope of at least 6 mm diameter (the 'governor rope') which passes from the safety gear linkage up the lift shaft, over a governor sheave, back down the shaft to the pit, around a tension sheave and back to the lift car, see Figure 6.29. In the event of the car exceeding a predetermined speed, the governor operates a device which grips and holds the governor rope, causing the safety gear to be applied. The downward motion of the car, or counterweight, is then arrested by friction between the wedges, rollers or jaws of the safety gear and the guide rails.

The governor must grip and hold the governor rope with a force of 300 N or twice the force required to engage the safety gear, whichever is greater.

With progressive safety gear, the car may slide some distance before stopping so the governor must allow the rope to move under force. This ensures that while the safety gear is properly engaged the weight of the lift is not directly placed on the governor or governor rope. Typically, the force required to engage the safety gear is 250 N whereas the force in the governor rope is 500–600 N.

The safety gear should also operate an electrical switch which disconnects the motor at, or before, the instant of application of the safety gear, see section 6.10.2.

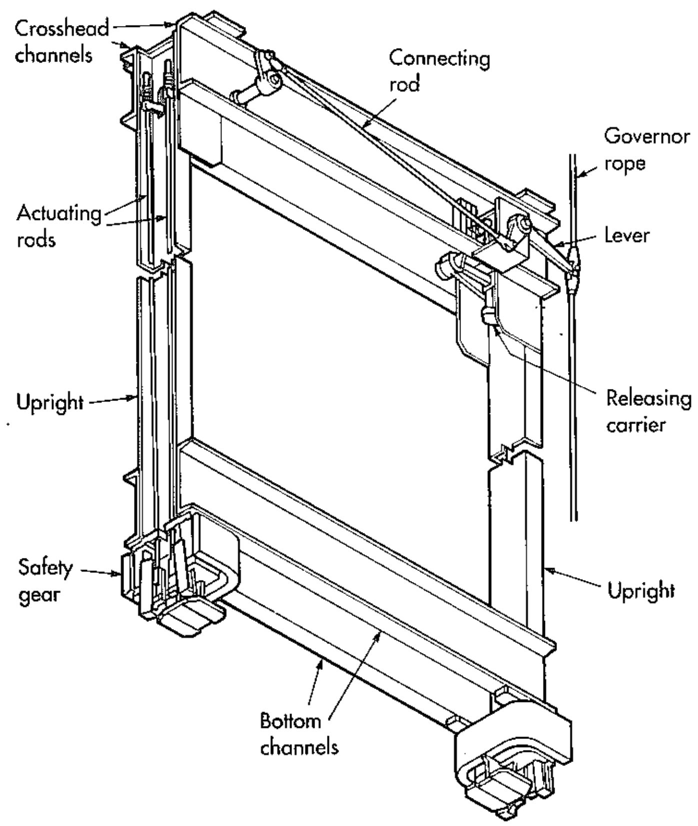

Figure 6.26 Car frame with progressive safety gear

6.11.7 Type-tested safety gear

Many types of safety gear are now available 'type-tested'. This means they have been laboratory tested in accordance with *BS 5655: Part 1*[1]. The tests required on-site after installation differ from those required for non-type tested safety gear. *BS 5655: Part 10*[9] states the test requirements for both types.

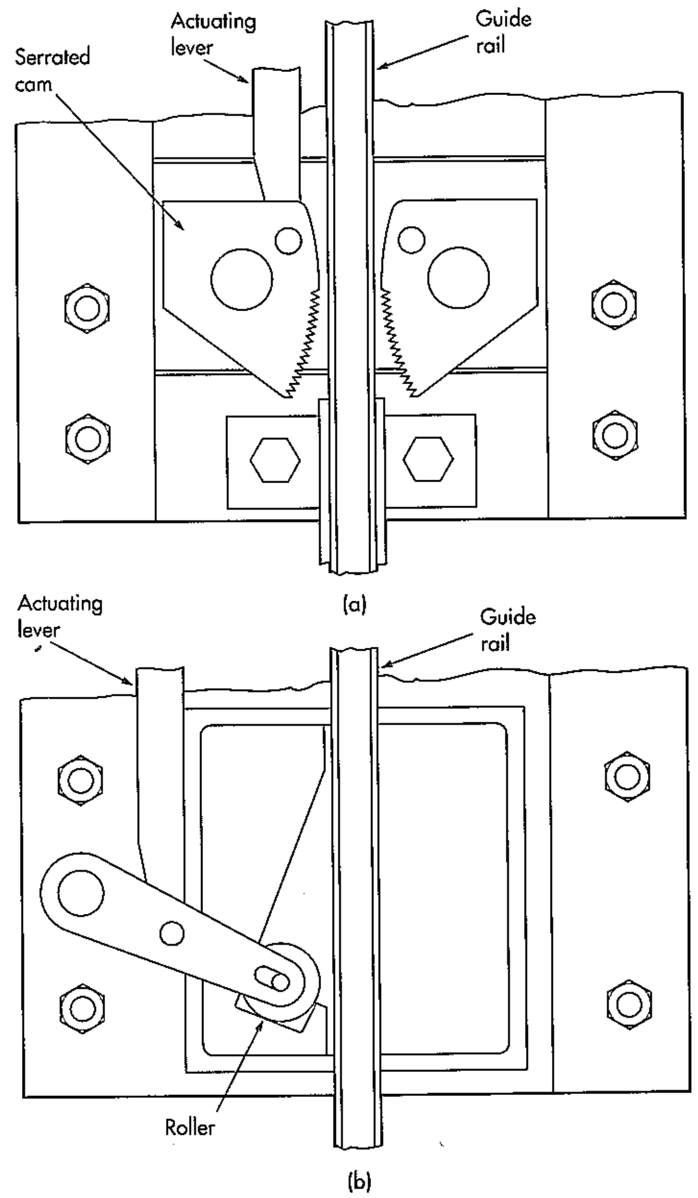

Figure 6.27 Instantaneous safety gear; (a) serrated cam, (b) roller type

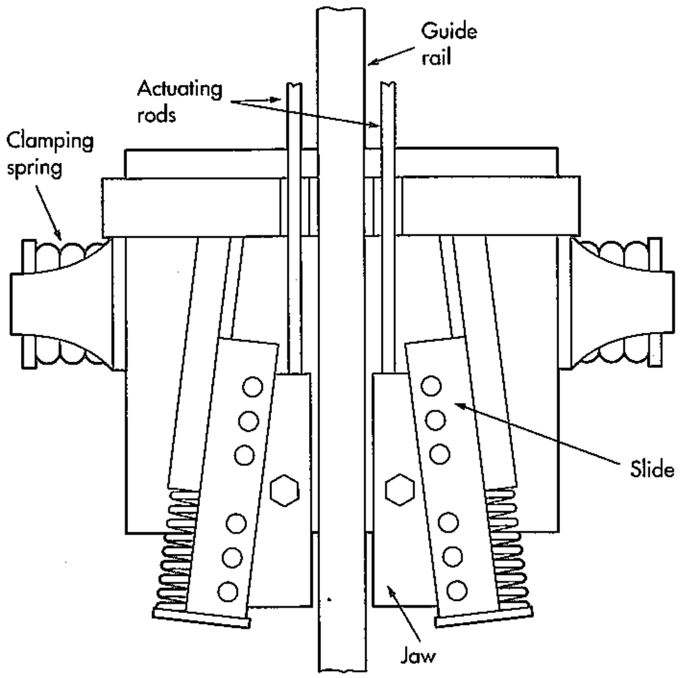

Figure 6.28 Progressive safety gear

6.12 Buffers

6.12.1 General

Buffers are placed below the car and counterweight to arrest either should one or other overtravel into the lift pit. In the case of positive drive lifts buffers are also required at the top of the shaft or on top of the car.

The number of buffers will vary according to the design capacity of the buffers and the load to be stopped, but the stroke is dependent on the speed of the car or counterweight.

There are two basic types of buffers: energy accumulation types using springs or rubber, and energy dissipation types such as hydraulic buffers. These are illustrated in Figure 6.30.

6.12.2 Energy accumulation buffers

The kinetic energy is stored in the gradual compression of springs or rubber blocks, which provides a progressive retarding force, see Figure 6.30(a). The rate of deceleration increases as they are compressed. Therefore the range of speeds for which they can be used is limited, i.e. for speeds up to 1.0 m/s, or up to 1.6 m/s if provided with a buffered return movement.

The distance the contact end of the buffer can move (i.e. the stroke) shall be at least equal to twice the gravity stopping distance corresponding to 115% of the contract speed, i.e:

$$s = 2 \times 0.0674\, v^2 \approx 0.135\, v^2 \qquad (6.1)$$

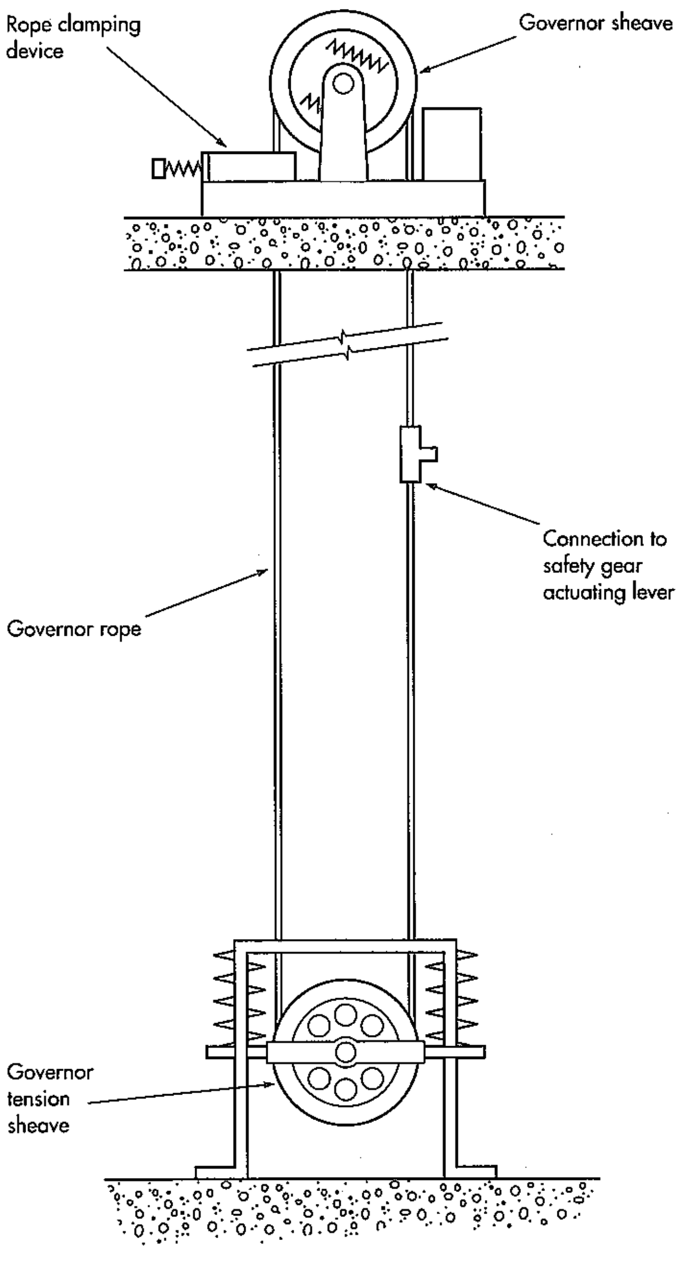

Figure 6.29 Governor rope — general arrangement

where s is the stroke (m) and v is the contract speed (m/s).

However, the stroke must not be less than 65 mm. The buffer must be able to cover this stroke under a static load of between 2.5 and 4 times the sum of the mass of the car and its load, see *BS 5655: Part 10*[9].

6.12.3 Energy dissipation buffers

The kinetic energy is dissipated by forcing oil through a series of holes, see Figure 6.30(b). Energy dissipation buffers provide a near constant rate of deceleration and are therefore suitable for all speeds.

The stroke (i.e. the distance moved by the buffer piston or plunger) required shall be at least equal to the gravity

stopping distance corresponding to 115% of the contract speed, see *BS 5655: Part 1*[1], i.e:

$$s = 0.0674\, v^2 \qquad (6.2)$$

It is permissible to reduce the stroke so as to avoid excessive pit depth, provided that additional speed monitoring equipment is installed to ensure that the car speed is reduced even under fault conditions at terminal floors. If such equipment is provided, the speed at which the car strikes the buffer may be used in the calculation instead of the contract speed. However, the stroke cannot be less than 50% of that resulting from equation 6.2 for lift speeds up to 4.0 m/s and not less than 33.3% for speeds above 4.0 m/s. In no circumstances should the stroke be less than 420 mm.

6.12.4 Type-tested buffers

Buffers are available type-tested and final testing at site should be carried out in accordance with *BS 5655: Part 10*[9]. Testing at full speed will not damage the buffers or the lift but the tests are severe and should not be repeated unnecessarily.

Energy dissipation buffers should be inspected after testing to check that they have not lost oil and have returned to their fully extended position. *BS 5655: Part 1*[1] requires an electrical switch to be fitted to ensure the car cannot run if the buffer is not fully extended.

6.13 Ropes

6.13.1 General

Ropes used for hoisting lift cars are of standard construction, each strand consisting of a number of wires. Strength and flexibility are the most important properties.

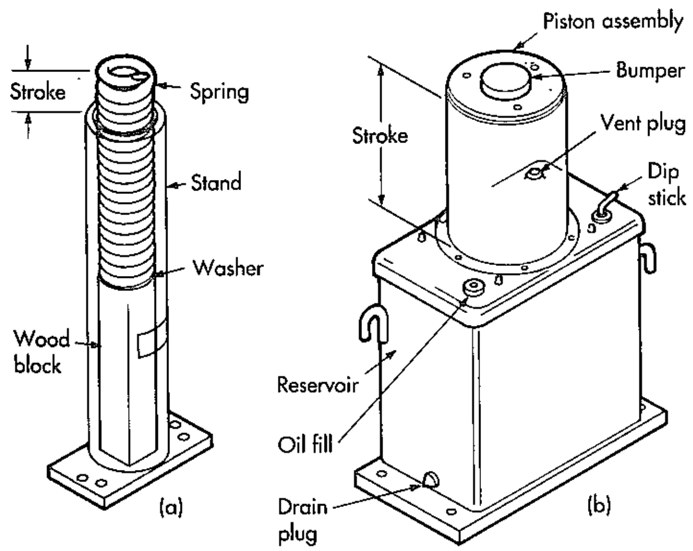

Figure 6.30 Buffers; (a) energy accumulation type, (b) energy dissipation type

The strength is obtained by the use of a steel with a high carbon content while flexibility is provided by the stranded construction.

6.13.2 Rope construction

Various rope constructions are used, and the size and tensile strength of the wires vary according to the construction. *BS 5655: Part 1*[1] states that the strength of wires for ropes of single tensile strength should be 1570 N/mm, 1770 N/mm or 1730 N/mm for the outer wires and 1770 N/mm for the inner wires of dual tensile strength ropes.

The wires are formed around a fibre core. This core is impregnated with a lubricant to reduce friction of the internal parts when in use and prevent corrosion when not in use.

Rope construction is referred to by numbers such as 6×19(9/9/1), see Figure 6.31(a). The first number, 6, indicates the number of strands used to form the rope while the second number, 19, indicates the number of wires used per strand. The way the strand is constructed is indicated by (9/9/1); nine outer wires around nine inner wires around a single central wire. A rope designated as 6×19(12/6+6F1), see Figure 6.31(b), indicates six strands each made up of 19 wires. The 19 wires are arranged with 12 on the outside, within which is a ring of six wires, plus six smaller 'filler' wires (i.e. 'F') around a single central wire.

Conventional lift ropes use wires of round sections, see Figure 6.31(a) and (b). In the dyform rope, the outer wires are not of simple circular section but are shaped to provide a larger exposed area, see Figure 6.36(c). This results in an increased breaking load, reduced stretch, and maintains fatigue resistance. Dyform ropes have been developed for high-speed high-rise applications but may also be used for other applications.

6.13.3 Rope sizes

The size of a rope is its nominal diameter which, for lifts, is usually between 8 and 22 mm, according to the strengths required. The most common sizes are 11, 13, 16 and 19 mm.

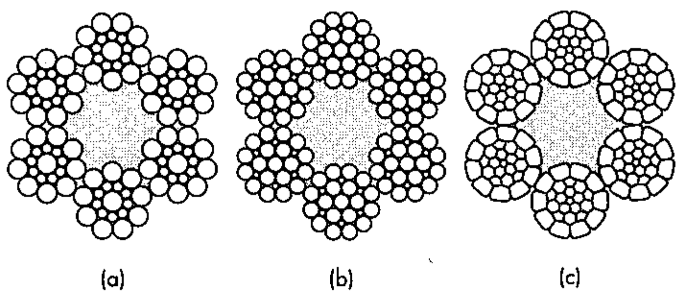

Figure 6.31 Types of rope construction; (a) 6×19(9/9/1), (b) 6×19(12/6+6F1), (c) 6×26 Dyform rope with fibre core

The diameter is that of the circumscribed circle and is measured over each pair of opposite strands. *BS 302: Part 4*[10] specifies that the actual diameter when supplied is that measured with the rope under a tension of 10% of the minimum breaking load. The size shall be within +3% and –0% of the nominal diameter. Some special ropes may be manufactured to even tighter tolerances.

6.13.4 Rope lays

Generally, two types of lay are employed in lift ropes: Lang's lay and the 'ordinary' lay, see Figure 6.32.

In the Lang's lay, the direction of the twisting of wires in the strand is the same as the direction of the twisting of the strands that form the rope, see Figure 6.32(a). The advantages of this arrangement over the ordinary lay are that it offers a greater wearing surface when in use and therefore a longer life. It is also more flexible but the rope is easy to kink if mishandled during installation and any benefits are then lost.

In the ordinary lay, see Figure 6.32(b), the wires in the strand are twisted in the opposite direction to the strands in the rope. Ordinary lay ropes are now used more frequently because they are more tolerant of mishandling and, provided the rope and sheave system is properly designed, give adequate life.

For both Lang's and ordinary lays, the length of lay of a rope is the distance, measured parallel to the axis of the rope, in which a strand makes one complete turn about the axis of the rope. The length of lay of a strand, similarly, is the distance in which a wire makes one complete turn about the axis of the strand. The rope strands can rotate either clockwise (right hand) or anti-clockwise (left hand) for both types of lay.

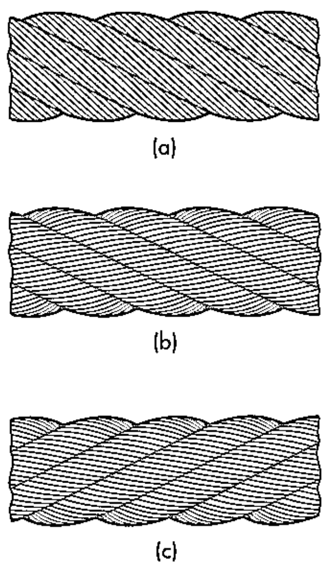

Figure 6.32 Rope lays; (a) Lang's lay, (b) ordinary lay, right hand, (c) ordinary lay, left hand

6.13.5 Safety factor for ropes

The safety factor is the ratio between the minimum breaking load of core rope and the maximum force in the rope when the car is stationary at the lowest landing.

$$S_r = n F K / w \qquad (6.3)$$

where S_r is the safety factor for the rope, n is the number of separate suspension ropes, F is the nominal breaking strength of one rope (N), K is the roping factor (1 for 1:1, 2 for 2:1, etc.) and w is the load suspended on the ropes with the car at rest at the lowest floor (N).

The load suspended includes the weight of the rope, the car and load, a percentage of the suspension ropes plus a percentage of the compensation, if provided.

BS 5655: Part 1[1] states that a safety factor of 12 shall be used for traction lifts with three or more ropes; 16 in the case of traction drive with two ropes, and 12 for drum drive arrangements.

6.13.6 Terminations

Various methods of terminating the rope are available, the most common being bulldog grips, swaged and socketed, see Figure 6.33. Whichever form of termination is used, its strength should equal at least 80% of the minimum breaking load of the rope.

With bulldog grips, see Figure 6.33(a), it is important to use the correct number, tightened to the correct torque. Where socket terminations are used, the ends of the rope are bent over and tucked into the socket, see Figure 6.33(c). The socket is then filled with white metal (also known as babbitt) or resin.

6.13.7 Rope length

When installed on a traction lift, the rope length should be such that when the car is on its buffers, and the buffers are fully compressed, the counterweight is clear of the underside of top of the lift shaft or any other obstruction. When the counterweight rests on its fully compressed buffers, no part of the car may touch the top of the shaft or any obstruction in it. The actual clearance depends upon car speed. *BS 5655: Part 1*[1] provides guidance on these dimensions.

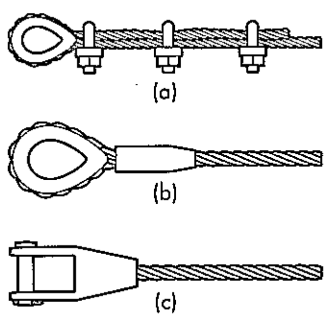

Figure 6.33 Rope terminations; (a) bulldog grip, (b) swaged end, (c) socket end

6.14 Roping systems

6.14.1 General

There are many different roping systems, some of which are shown in Figure 6.34. The best method to employ will depend upon the particular situation, e.g. machine position, available headroom, contract load and speed. However, whatever the requirements, the simpler the roping system the better.

The lift machine is usually situated either at (or near) the top or bottom of the shaft. All types of electric traction drive are suitable for either top or bottom drive, but the best, and simplest, roping system is with the machine at the top. This usually provides the best rope life, lowest capital cost, least power consumption and minimum structural loads. Bottom drive is generally mechanically more complex in its roping arrangement and hence more expensive than top drive.

Typically, the structural load applied to a building with the machine above is the total weight of the lift machine, control gear, car, car load and counterweight. With the machine below, the structural load is approximately twice the sum of the weight of car, car load and counterweight. If the weight of the machine and control gear is considerably greater than the combined weights of the car, car load and counterweight, the structural load may be less with the machine below, but this is unusual.

For a machine located at the top of the building, the simplest rope arrangement is that of the single wrap 1:1 system in which the ropes pass over the traction sheave once and the rope ends are terminated at the car and counterweight, see Figure 6.34(a). With this system, the car travels 1 m for every metre of rope moved over the traction sheave.

Figure 6.34(b) shows a 1:1 arrangement with the machine located below. This arrangement removes the need for a full height machine room at the top of the building, but space for the sheave will still be required. The saving is generally about 900 mm in height but extra costs may result due to the additional rope and sheaves.

With a 2:1 roping system, the car travels 0.5 metres for every metre of rope moved over the traction sheave. This means that the speed of the car is half that of the driving machine. Either top- or bottom-located machines may be used with a 2:1 roping system.

An advantage of this arrangement is that it enables a small number of machines to cover a wider range of speeds and loads since, by halving the speed, the load may be doubled.

In addition, the load imposed on the machine sheave shaft is effectively halved as half the mass of the car and half the mass of the counterweight is supported by the building structure, see Figure 6.34(c). The reduction in the load carried by the ropes passing over the traction sheave reduces rope pressure and may enable fewer ropes to be used. The system does, however, require longer ropes and rope life may be reduced by the additional bending stress caused by the number of sheaves that the ropes must pass over.

Where bottom drive is employed, a reduction in headroom may be obtained using an underslung arrangement for the lift car. This involves mounting pulleys on the underside of the car and positioning high-level pulleys and rope anchorages (outside the line of the car roof) at the top of the lift shaft, see Figure 6.34(h). No pulley room is required with this arrangement. It should be noted that increased running noise may be apparent with the underslung arrangement, therefore speeds are usually limited to 1.6 m/s.

Many other rope systems have been used, such as 3:1 (see Figure 6.34(d)) but these are not commonly used except for very large goods lifts or other special applications.

6.14.2 Compensating ropes

Ropes may be hung under the car to the counterweight in order to compensate for the weight of main ropes, see Figure 6.34(g). Compensation is used to ensure that adequate traction is available, wherever the car is in the shaft, and/or to reduce the power requirement for the drive motor.

For lifts up to 2.5 m/s, chains or free ropes may be used, tensioned by gravity. For speeds above 2.5 m/s, a tensioning device is required. This usually takes the form of a weighted sheave fixed between two guides. For speeds above 3.5 m/s, an anti-rebound device is required. This prevents the counterweight from rising through its own inertia if the car should be stopped abruptly, and prevents the car from continuing upwards if the counterweight should be stopped suddenly. This is sometimes referred to as 'tied-down' compensation, see section 6.6.4.

6.14.3 Traction systems

In all rope systems, the power developed by the machine is transmitted to the ropes either by a single- or double-wrap traction system. In the single-wrap system the ropes pass once over the sheave, into which specially shaped grooves are cut. These are known as traction grooves. The traction force depends on the friction between the ropes and the sheave, the groove angle and the amount by which the ropes wrap around the sheave.

These factors govern the ratio which can exist between the rope tensions on the two sides of the sheave before slipping occurs. The traction developed must be sufficient to enable the car plus 125% load to be safely supported but must be low enough to ensure that, if the tension in either the car or counterweight side of the rope is reduced to zero, the traction will be insufficient to permit the car or counterweight to be hoisted. Excessive traction will also result in excessive sheave and rope wear. *BS 5655: Part 1*[1] provides formulae for the calculation of traction.

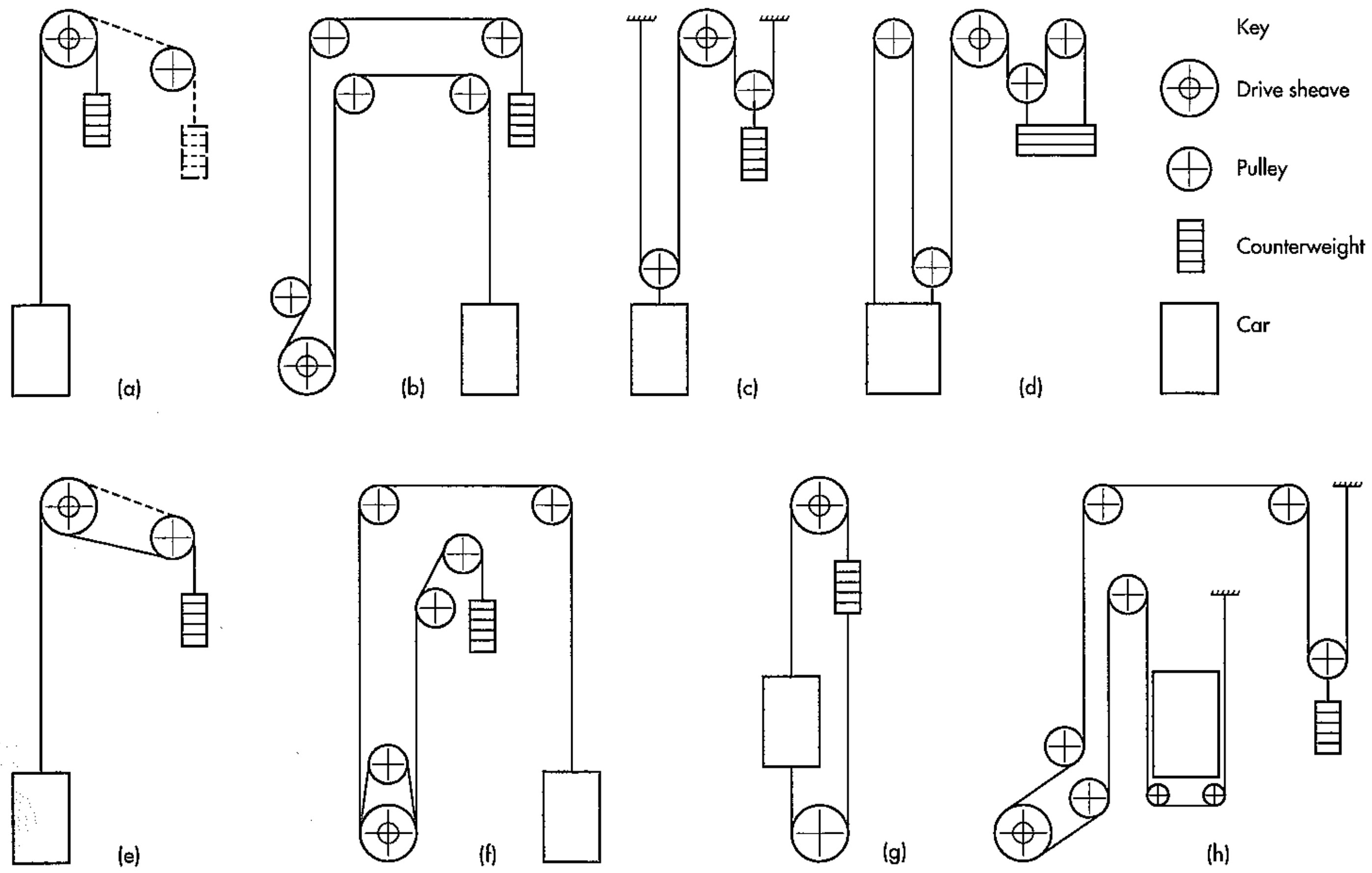

Figure 6.34 Roping systems; (a) 1:1 single wrap, machine above, (b) 1:1 single wrap, machine below, (c) 2:1 single wrap, machine above, (d) 3:1 single wrap, machine above, (e) 1:1 double wrap, machine above, (f) 1:1 double wrap, machine below, (g) 1:1 machine above with compensation, (h) 2:1 single wrap, machine below, underslung car

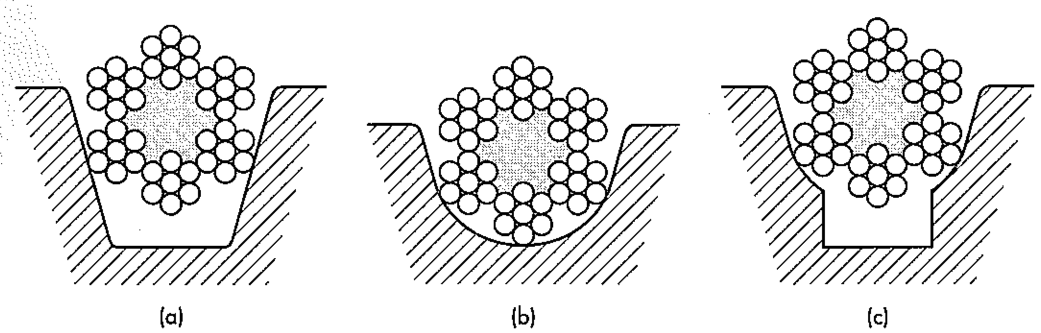

Figure 6.35 Common types of groove; (a) 'V' groove, (b) round seat ('U' groove), (c) progressive or undercut groove

The shape of the groove has a considerable influence on the tractive force. Figure 6.35 shows typical grooves that may be employed. The straight V-shape provides the greatest traction, the least support to the rope and, therefore, the greatest wear. The round-seat type provides the most support and the least traction and wear.

The number of variables involved in the traction and rope life means that it is unreasonable to request a particular groove or material and the manufacturer should be allowed to provide the combination that it feels to be the most appropriate. Ropes may be expected to last seven to ten years for the lifts in a typical office building. However, this may not be achievable in environments such as large hotels, where lifts may operate for up to 20 hours per day.

6.15 Car and landing fixtures

6.15.1 General

The term fixtures embraces car operating panels, indicators, push buttons, hall lanterns and any signs, magnetic card readers or key-pads. If properly designed, they can help to make a lift appear 'user friendly' and will improve service. While these items will contribute greatly to the appearance of the lift, their prime function is to inform users of what is happening and/or to enable instructions to be given to the lift control system.

Essential fixtures such as buttons, indicators and hall lanterns should be large, conspicuous and easy to see against the surrounding walls.

6.15.2 Push buttons

Buttons may be square, round or any other shape. Some means of informing users that their call has been registered is good practice and this may be by illumination of the button or surrounding halo or by a separate indicator. Illumination is best provided by light emitting diodes (LEDs), which give long trouble-free life. Face plates should be of sufficient size to make the buttons easily noticed. Buttons without face plates are difficult to spot and therefore should never be installed on landings without a face plate.

Markings on buttons should be in a clearly, easily read typeface such as helvetica and, if possible, by some form of tactile indicator. Braille markings are sometimes provided but are of little help since the majority of persons with impaired vision cannot read Braille. Simple tactile markings are preferred since these are discernible by all.

6.15.3 Lift position indicators

Preferably indicators should be provided within the car and on the main landing. On single units, an indicator at all floors is a useful addition which provides users with a visible indication of the lift's progress. It may be desirable to indicate when lift cars are unavailable for passenger use, although this is not required by *BS 5655: Part 1*[1]. On non-collective lifts, a 'lift busy' indicator is necessary so that users know that the lift cannot accept calls.

When two or more lifts are operating together, it may be better not to provide indicators on every landing but only at the main entrance floor for the building. Some lift systems deliberately order a car to bypass a call to optimise overall response times. Passengers observing this operating sequence are likely to interpret it as a fault.

Figure 6.36 illustrates three types of indicators; multi-light, dial and digital.

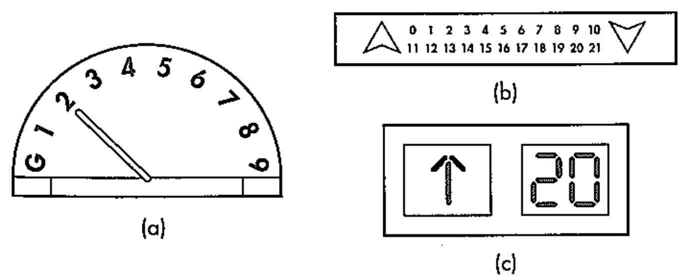

Figure 6.36 Lift position indicators; (a) multilight, (b) dial type, (c) combined hall lantern and digital indicator

Incandescent bulbs are not a good choice for position indication since they consume more energy and have a shorter life than other forms of illumination. On large groups, indicator bulb replacement can become a frequent maintenance task. The power requirements are illustrated by the fact that the car lighting and indication can consume half the total energy required to run the lift.

Digital-type indicators are by far the most popular and many versions exist. Illumination may be by vacuum fluorescent display or solid-state indication using LEDs. LED displays provide a compact, energy efficient solution. Dot matrix displays allow great flexibility in floor identification. Large dot matrix displays can be used to display messages which can be read easily from anywhere in the car.

Whichever type is chosen, the display should be clear to all users including the partially sighted. Voice annunciators are useful in situations where the lifts are regularly used by the general public or by blind or partially sighted people. However, the announcements can become a source of irritation to lift users.

Fixtures should be displayed against a dark background to provide a sharp contrast in colour and should be visible from acute angles, especially where there is only one indicator, placed to one side of the car entrance. In large cars (i.e. 1600 kg and above), two operating panels, each with an indicator, should be considered.

6.15.4 Lift direction indicators

On any simplex collective lift, passengers should be provided with a means of determining the direction of travel of the car before they enter. This can be achieved by providing a hall lantern or direction indicator at each landing or a single direction indicator within the car, positioned so as to be visible when the doors open. Again illuminations by LEDs or vacuum display is preferable because of their high reliability.

6.15.5 Hall lanterns

Hall lanterns should always be provided at each landing for groups of two or more cars and may be provided on single lifts, if desired. The lantern should illuminate and chime before the car arrives at the floor to alert waiting passengers. This enables the passengers to start moving toward the arriving lift so that door dwell times can be kept to a minimum. To assist the partially sighted, the chime should emit notes of different tones or sound once for up and twice for down.

Numerous designs are available but again the essential points are reliability and practicality. It must be borne in mind that the principal function of lanterns is to provide the passengers with information.

References

1 *BS 5655: Lifts and service lifts: Part 1: 1986: Safety rules for the construction and installation of electric lifts* (London: British Standards Institution) (1986)

2 *BS 721: Specification for worm gearing: Part 1: 1963 (1984): Imperial units; Part 2: 1983: Metric units* (London: British Standards Institution) (dates as indicated)

3 *BS 5655: Lifts and service lifts: Part 5: 1989: Specification for dimensions of standard electric lift arrangements* (London: British Standards Institution) (1989)

4 *BS 5655: Lifts and service lifts: Part 11: 1989: Recommendations for the installation of new, and the modernization of, hydraulic lifts in existing buildings* (London: British Standards Institution) (1989)

5 *BS 5655: Lifts and service lifts: Part 2: 1988: Safety rules for the construction and installation of hydraulic lifts* (London: British Standards Institution) (1988)

6 *BS 5655: Lifts and service lifts: Part 9: 1985: Specification for guide rails* (London: British Standards Institution) (1985)

7 *BS 5655: Lifts and service lifts: Part 7: 1983: Specification for manual control devices, indicators and additional fittings* (London: British Standards Institution) (1983)

8 *BS 476: Fire tests on building materials and structures: Part 22: 1987: Methods for determination of the fire resistance of load bearing elements of construction* (London: British Standards Institution) (1987)

9 *BS 5655: Lifts and service lifts: Part 10: 1986: Specification for testing and inspection of electric and hydraulic lifts* (London: British Standards Institution) (1986)

10 *BS 302: Stranded steel wire ropes: Part 4: 1987: Specification for ropes for lifts* (London: British Standards Institution) (1987)

7 Lift controls

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Contents

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7 Lift controls

7.1 Introduction

The objective of this section is to provide an unbiased guide to lift controls so that users and specifiers may compare manufacturers' products and have confidence that they are specifying the correct control equipment for each application. It is intended to help the reader to look for good and bad features and to be in a position to ask the right questions about manufacturers' products. Documentary proof of performance, reliability and control characteristics should always be requested from the manufacturer in case of uncertainty.

Until the 1980s, buildings and users have often suffered because of the incorrect application of lift products to the building. In many cases, this was due to speculative building decisions, providing less than the optimum number of lifts for the building. In other cases, the specifier has taken incorrect advice from lift salesmen. Changes in office working practices and the cost of office accommodation have also resulted in problems. Both can lead to the building population increasing far beyond the capabilities of the existing lift control systems. In these cases, installing new solid-state and computer-based equipment may improve the passenger-handling capacity of existing groups of lift cars.

7.1.1 Performance parameters

The controller influences the efficiency of a given group of lifts to move people. Parameters such as flight times, round trip times and interval (see section 3) provide a guide to the relative efficiency and these parameters can be either measured or obtained from the lift supplier. As an example, one second saved on single floor transit time (see section 3.6.3) improves the traffic handling capacity of the lift by approximately 5%.

To maximise the transportation capacity for a given size and speed of lift car, the cycle time must be as short as possible. In practical terms this means that:

— the lift should drive straight to floor level without the need for a slower levelling speed to ensure accurate stopping at floor level and a short single-floor flight time

— the opening time for the doors must be short; this time may overlap with levelling

— the door open time must be optimised to the building type, size of the lift car and passenger movement; non-contact passenger detectors (see section 6.7.6) can be used to shorten the door open time.

— the door closing time should be as short as possible, commensurate with the kinetic energy limitations imposed by *BS 5655: Part 1*[1] (see section 6.7.2).

These factors have important consequences for the design of lift components and control devices.

7.1.2 Operation monitoring

In the past, lift controllers have provided little information on the operational state of the lifts. This information has been typically confined to:

— lift position indication on landings and in the car

— actual and intended travel direction

— lift-in-use indication for simpler lifts using automatic push button control.

Passenger alarm indication is typically by an audible warning device mounted on or near the lift with remote indication at a porter's desk or similar location.

Computer-based control systems have resulted in the development of more sophisticated monitoring of the state of the lift and its traffic handling efficiency. Features typically available include:

— add-on or built-in fault detection and diagnosis

— statistics on call handling and lift usage

— communications capability for transmission of information to a remote point

— video monitor displays of the real-time operation of the lift group(s)

— voice annunciation of lift position and other messages.

Groups of lifts in busy public use, e.g. those in airports and hospitals, should always have some form of lift monitoring, either local to or remote from the building. If monitoring of small groups or individual lifts is installed for maintenance purposes, the equipment local to the lift should not be over-complex. The monitored information must be checked for accuracy and relevance. False or irrelevant information can be worse than no information at all.

Most manufacturers have their own solutions to lift monitoring which, in the main, rely on special computer software and it is essential to consult with the potential suppliers before specifying non-standard monitoring equipment (see section 10). It is rarely cost-effective for manufacturers to design one-off software for individual customers. Furthermore, it may prove difficult to locate a maintenance company willing to accept responsibility for such software.

7.2 Lift controllers

7.2.1 General

The function of a lift controller is to respond to inputs and produce outputs in order to control and monitor all the operations of an individual lift car. The controller may be considered to comprise power control (i.e. motion control, door control) and traffic control (passenger demands).

The power controller must control the lift drive motion so that the lift always achieves the optimum speed for any travel distance. Uneven floor heights must not result in long periods of low speed travel when slowing to some floors.

The power controller must also operate the doors and modify the opening time and speed of the doors in response to signals from the passenger detectors.

In general, the controller inputs are:

- car calls
- landing calls (direct or from a group controller)
- door safety device signals
- lift well safety signals
- signals from passenger detection devices on car, doors and landings.

The controller outputs are:

- door control signals
- lift drive control signals
- passenger signalling (call acceptance, lift position, direction of travel indication).

The basic traffic control task of moving a lift car in response to calls is trivial. However, two factors combine to make the lift controller one of the most complex logic controllers to be found in any control situation. These are:

- control options
- fail-safe operation if faults occur.

7.2.2 Lift control options

Lift control options are customer-defined modes of operation of the lift. Many options are standard and defined in the operation sequence of the lift, and are offered by all major lift manufacturers. In some circumstances, the complexity or combination of options makes the use of computer-based controllers essential.

Among the most common options are:

- car preference or independent operation of one lift car
- rapid closing of doors, when a car call is registered
- reduction in door open time, when passengers are detected by interruption of the light ray or other passenger detection device
- differential door timing so that doors stay open longer at the main floor and/or vary according to the lift traffic
- 'door open' button
- 'door close' button
- attendant operation (becoming less common)
- recall of all or some lifts to specified floor(s) in the event of fire
- emergency power operation (the exact operational sequence is usually defined by the customer)
- bed service (for hospital lifts).

A detailed description of the operation of the particular lift manufacturers' version of these options should always be provided by the manufacturer when discussing the specification with the customer. This can avoid ambiguity and misunderstandings leading to excessive costs.

Other modes of operation may be specified by the customer. Where these modes are unique, it is important to note that they may require special computer software and/or controller hardware. The commissioning and maintenance of such special modes is not always as straightforward as that for conventional lifts.

7.2.3 Fail-safe operation

Safety requirements are laid down in *BS 5655: Part 1*[1] and *Part 2*[2] for electric traction and hydraulic lifts (other than home lifts) and *BS 5900*[3] for home lifts. These standards require that both the lift controller and the lift must be designed so that a single fault in the lift or the controller shall not cause a dangerous situation to arise for the lift user.

Note that the safety requirements and standards for lifts in the home are less rigorous than those for lifts in public areas and work places.

7.2.4 Controller cabinet

The size of controller cabinets varies with complexity of the controls. Most cabinets are between 0.8 and 2.5 m high. They should be installed plumb, square and securely fixed in place. They should not be located in awkward corners or restricted spaces that may cause servicing or safe-working problems. Control cabinets should be positioned such that they are not subjected to the heat resulting from machine ventilation fans. Adequate lighting should be provided and the environmental

conditions required by the manufacturer must be observed.

The physical arrangement of the components within the cabinet may cause the local temperature for some components to rise above the ambient temperature in the machine room by up to 10°C. All power resistors and high-temperature components should be mounted at the top of the cabinet to avoid undue heating of other components. The cabinet should be designed to allow a free flow of air from bottom to top of the controller without any fan assistance in order to limit the internal temperature rise to 10°C.

High humidity and rapid changes in temperature may cause condensation and these conditions should be avoided in the machine room. This is not a problem in most applications. However, where the environment is severe and condensation cannot be avoided, the following precautions should be considered:

- all equipment should be passivated or galvanised and extra coats of paint applied
- all components and printed circuit boards should be tropicalised
- forced ventilation of the cabinet should be considered.

7.3 Controller technology

7.3.1 General

The size of the building (i.e. number of floors) and the complexity of the lift operations required determine the technology used for the controller. The three basic controller technologies are electromagnetic relays, solid-state logic and computer-based ('intelligent') systems.

Computer-based systems offer the greatest flexibility to accommodate changes in the use of the building and the requirements of the user, and electromagnetic relays the least. However, electromagnetic relays and contactors are also used in computer-based and solid-state logic controllers in order to satisfy the safety requirements of the relevant British Standards[1–3].

7.3.2 Electromechanical switching

Electromechanical switching devices include electromagnetic relays and mechanically driven selectors. Relays are designed for low-power switching operations and contactors for higher powers. Lift selectors, mechanically driven from the motion of the lift by a tape or rope drive, may be used for low-power logic operations in lift control. Some manufacturers use tape drives for lift position indicators, even in computer-based controllers.

All electromechanical devices have a limited operational life. For relays and contactors, the mechanical life is typically between 10 and 30 million operations, depending on the type and manufacturer. The contact life depends on the ambient temperature, level of atmospheric pollution (e.g. dirt and chemical contaminants), contact current and type of load, and is typically between 2 and 3 million operations.

For a lift serving a typical office building, the number of relay operations may total 150 000 per year (based on an average rate of relay operations of 60 per hour for 10 hours per day and 250 days per year). The operating frequency for certain relays within the controller may be even higher. For example, some relays operate every time the lift passes a floor, resulting in approximately 250–300 operations per hour and hence, over a life of 10–12 years, a total of some 9 million operations.

For contactors used to control the lift hoist motor, brake and power, the minimum life is 1 million operations. This gives an average life of 6–7 years before replacement but does not allow for premature random failures.

To maximise the reliability of the lift controller, the number of electromechanical components should be kept to a minimum. The failure rate for relays is between 1 and 2 for every million hours of operation. With a controller using 50 relays, this gives a mean time between failures of between 16 000 and 30 000 hours (two to four years). For a 2000-hour operating period, the reliability factor is 0.88. Thus there is a significant probability that the lift will break down at least four times a year because of relay problems.

When a relay controller is 8–10 years old, the breakdown rate of the lift rapidly increases as the relays wear out. O'Connor[4] gives intermittent faults as 70% of relay failures during the wear-out phase.

For mechanical lift selectors, reliability problems occur because of the mechanical complexity and the difficulty of keeping these devices correctly adjusted. Adjustment is particularly difficult where the selector controls the stopping point of the lift. In these circumstances, a small displacement of the stopping point contact on the selector causes a larger error in the accuracy of lift levelling. The use of such devices is now declining.

Relay-based controllers have often presented maintenance problems when fitted to larger lifts and group systems (see section 7.6.5). Often, manufacturers do not include sufficient indicator lights to show the operational state of the relays. In cases of intermittent faults, this lack of indicators can increase repair times unnecessarily. Although the controller drawings are on site, they often do not show the actual circuits, because modifications may have been made, without the appropriate changes being made to the circuit diagrams.

The following applications may be recommended as suitable for controllers using electromagnetic relay technology. However, the cost implications (both capital and recurrent) are likely to restrict their application.

- single lifts only (electric traction or hydraulic drive)

- drive speeds up to 1 m/s
- passenger lifts in low traffic and usage situations in low-rise buildings, i.e. not more than three storeys (e.g. residential buildings, very small hotels, nursing homes)
- goods, bullion lifts in low-rise commercial buildings (e.g. offices, hotels, hospitals).

7.3.3 Solid-state logic technology

Solid-state logic technology includes both discrete transistor circuits and integrated circuit boards. Solid-state logic gives improved reliability, lower power consumption and easier fault diagnosis than electromagnetic relay technology, and is easier to adapt for lift control options. With integrated circuits based on complementary metal oxide silicon (CMOS), 12–15 V power supplies may be used, which provide high immunity to electrical noise interference.

Call signals and other direct current input signals are usually interfaced via passive filter circuits. Light-emitting diodes (LEDs) may be easily incorporated into the design to aid maintainability. It is still necessary to use some contactors and relays to satisfy requirements of *BS 5655*[1,2] and *BS 5900*[3]. Small cased relays may be used to interface between logic circuits and the high voltage parts of the controller and lift. Figure 7.1 illustrates the basic features.

The reliability of solid-state logic devices is dependent upon the ambient temperature, the operating point of the

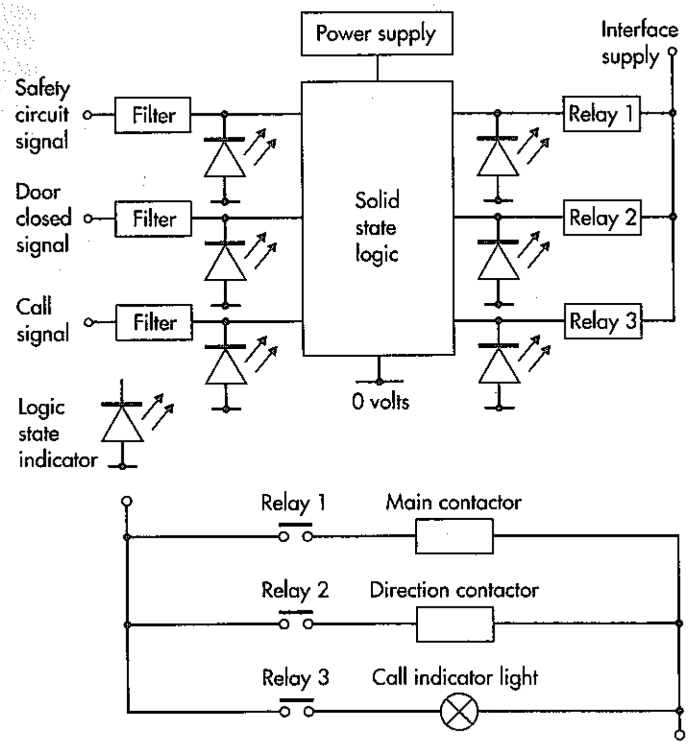

Figure 7.1 Schematic of typical solid-state logic controller

device (in relation to its maximum rating) and the complexity of the device. The following points should be considered to ensure maximum life:

- Increasing the ambient temperature by 25°C increases the failure rate of a device by a factor of 10. Therefore, the lift motor room should be kept as cool as possible while staying within the minimum set by *BS 5655: Part 6*[5] of 5°C for electric traction and 15°C for hydraulic drive (see section 9.2).
- Running a solid-state device at 70–80% of its maximum rating doubles its reliability compared with running at maximum rating.
- The failure rate of digital integrated circuits is proportional to the number of basic logic circuits (gates) in the device. The failure rate of a 1000-gate device operating in an ambient temperature of 40°C is about 0.2 per million hours of operation.

Unlike electromagnetic relays, the life of solid-state devices is not limited by mechanical operation and wear. Breakdowns are also generally easier to identify because they are often due to complete failure of the device, rather than to intermittent faults.

One common source of unreliability in solid-state controllers is the connectors. For lifts, printed circuit boards should use the highest quality two-part (e.g. DIN type) rather than edge connectors, since the latter are prone to intermittent contact problems in low voltage, low current applications, where the atmospheric conditions are unfavourable

With the advent of application-specific integrated circuits (ASICs), the number of chips used in an application can be reduced. This improves reliability and allows lift options to be included as standard. These options can be easily selected to produce a specific controller tailored to meet particular requirements.

Integrated circuits allow lift controllers to incorporate many lift options and are suitable for single and duplex lifts, where there is a low density of traffic. The following applications are recommended as suitable for controllers using solid-state logic technology:

- single lifts and duplex (i.e. two-lift) groups (electric traction or hydraulic drive)
- drive speeds up to 2 m/s
- passenger lifts in low traffic situations in medium-rise buildings, i.e. up to 12 storeys (e.g. residential buildings, small hotels)
- goods, bullion lifts in commercial buildings (e.g. offices, hotels, hospitals).

7.3.4 Computer-based technology

Computer-based technology enables complex and adaptable functions to be performed. However, non-standard features should be avoided because of the expense involved in developing and testing special computer software.

Computer-based controllers offer flexibility in the options provided and permit fine-tuning to match the building requirements. They are the preferred choice for lift groups of any size and for all lift traffic situations other than low density.

The following features should be provided to ensure adaptability and trouble-free operation:

- isolated floating power supply for the computer (i.e. not connected to the electrical safety earth or supply common)
- power supply regulator with a high input/output voltage differential to ensure immunity from fluctuations in the mains supply
- galvanic isolation (also known as opto-isolation) of all inputs and outputs to the computer to reduce pick-up of electrical noise and possible destruction of low-voltage components
- program written in a high-level language for ease of program maintenance
- real-time operating system to control lift program execution
- diagnostic capability to monitor performance and record basic information to aid fault diagnosis
- visual indicators on key input and output signals to aid maintenance
- means of altering lift parameters (e.g. door times, parking floor) on site, without the use of special programming equipment or replacement programs.

The basic reliability of computer-based devices is the same as for solid-state devices. However, considerably improved reliability is achievable if the hardware and software are engineered carefully.

The construction of the computer, programming and its interface to the rest of the lift controller profoundly affects the reliability of the controller.

Software also affects reliability. The use of a high-level language is essential for all but the simplest programs. It is necessary to test thoroughly new software and software modifications to ensure that any programming errors cannot cause lift malfunctions.

Computer-based controllers are suitable for:

- all types of lifts
- all drive speeds (i.e. 0.5 to 10 m/s)
- lift groups of all sizes (see also section 7.6). The group control function should have at least one level of backup to ensure continued landing call service if the main group control fails.

7.4 Control of lift drives

7.4.1 General

Drives for lifts are separated into two main categories; electric traction (see section 6.2) and hydraulic drive (see section 6.3). Electric traction drives are further divided into geared and gearless drives. It should also be noted that hydraulic lifts also use electric motors for driving the hydraulic pump.

The characteristics and applications of each type of drive vary considerably and an inappropriate drive can have disastrous effects on the reliability and efficiency of the lift installation. It may also lead to increased capital and recurrent costs for the building.

Irrespective of space considerations, the key parameters in choosing between hydraulic or electric traction lifts are as follows:

- height of travel
- projected number of starts per hour
- required ride quality
- nominal lift speed to provide an acceptable transit time between terminal floors of the building (e.g. 20–40 s)
- number of lifts required to move the projected building population.

As a general guide, hydraulic lifts should not be specified if the number of motor starts per hour is likely to exceed 45 (or 120 if additional oil cooling is provided, see section 9.5.2), or if more than two lifts are necessary to move the population efficiently. This is because the temperature of the oil is very important for reliable operation and most of the energy from the motor is dissipated in the oil, causing its temperature to rise. However, it should be noted that for hydraulic lifts, which do not use a counterweight, the number of motor starts is not equal to the number of lift starts since, for travel in the down direction, only the fluid control valve is opened.

The ride quality of hydraulic lifts at high speeds is generally inferior to that of controlled electric traction drives. For goods and service lifts, however, this is of minor importance provided that levelling accuracy is not compromised.

7.4.2 Motor speed reference

The motor speed reference is a control signal generated by some device, which indicates the speed and direction of movement of the lift. Some motor speed reference generators also provide information on the present position of the car. These signals are used to control the speed and direction of the motor to enable the lift to respond to instructions received from the controller.

Motor speed references may be divided into two categories; time-based and distance-based[6]. In general, provided that the motor speed is accurately controlled and stable under all likely environmental and load conditions, the distance-based speed reference provides better control, maximum handling capacity and superior ride comfort. It also ensures minimum energy consumption for a given handling capacity.

7.4.2.1 Time-based speed reference

Figure 7.2 shows a typical velocity/time graph for a time-based speed reference. The speed reference is generated by a simple analogue computer in response to a lift call. It has preset acceleration and deceleration values but, often, no predefined value of jerk. At the start of a run between floors the speed reference increases to the maximum speed for multifloor runs. For one-floor runs, the speed is limited to an intermediate value determined by the shortest interfloor distance. For lifts with speeds greater than 1.5 m/s, two or more intermediate speeds may be used for two- and three-floor runs, where the lift does not reach its maximum speed.

For time-based speed generators, there is no feedback of lift position to the reference generator. Furthermore, since the lift position during deceleration is dependent upon the load, it is not possible for the controller to bring the lift to rest at floor level by means of constant deceleration. This difficulty is overcome by ensuring that, as the car nears the required floor, its speed is reduced to a constant 'approach speed', typically 0.4 to 0.5 m/s, and then further reduced to a 'levelling speed' of about 0.15 m/s, just before the car reaches floor level.

Deceleration is initiated at one or more fixed points in the shaft. The speed reference causes the lift to decelerate at a constant rate, until it reaches a second point at which the approach speed is set. The lift then runs at constant speed until a third point is reached at which the speed reference causes further deceleration to the levelling speed. The lift is finally brought to a standstill, either by the brake or by electrical regeneration in response to a signal from a position sensor.

It is not uncommon for poorly adjusted lifts to run at approach and levelling speeds for four or five seconds.

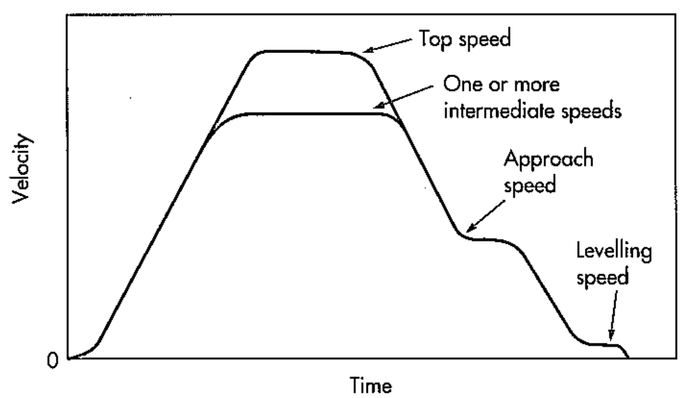

Figure 7.2 Velocity/time graph for time-based speed reference

7.4.2.2 Distance-based speed reference

Figure 7.3 shows a typical velocity/time graph for a distance-based speed reference, also known as optimal speed reference. The acceleration and deceleration values are preset with a predefined value of jerk.

There are no intermediate speeds used for short distance travel, where the lift cannot attain rated speed. The speed reference generator has inputs, which are dependent on lift position and velocity. These allow the reference to generate the maximum possible speed for the distance to be travelled.

For speeds of up to approximately 1.6 m/s, signals from devices mounted on the car or in the lift well are used to initiate deceleration. Because the speed of the lift is known at the signal point, the deceleration distance can be calculated by the speed reference generator. The start of deceleration can be immediate or delayed corresponding to the actual lift speed. During deceleration, the distance from floor level is calculated continuously and the braking torque applied to the motor is varied to maintain the lift on the required velocity distance curve.

For high lift speeds up to 10 m/s and buildings with several uneven interfloor distances, it is common to use a digital counter-based lift position and deceleration system. This technique can resolve the lift position in the shaft to an accuracy of 3 mm/count. The counter input is usually derived directly from a pulse generator connected to the lift or from a motor speed transducer. Typically, to correct for possible counting errors, a spatial image of the lift well is stored in computer memory and used for error correction, whenever the lift is running.

Using the stored image of the well and information derived from it, the speed reference is continuously provided with information on the distance the lift needs to travel to the next possible stopping point. Using this information, the speed reference determines the maximum possible speed for the distance the lift has to travel. The lift is decelerated in the same way, as described above for lower speed lifts.

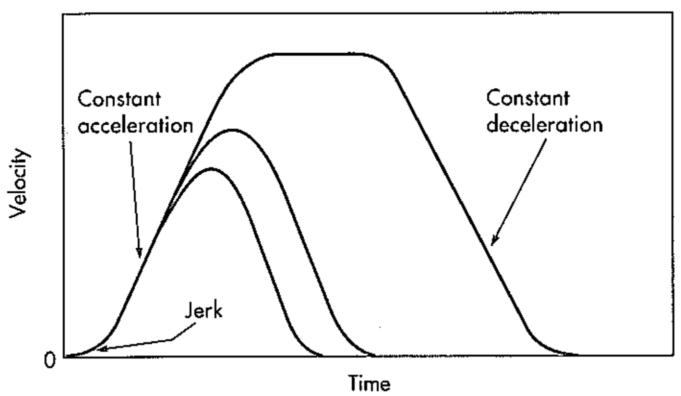

Figure 7.3 Velocity/time graph for distance-based speed reference

7.4.3 Protection against failure of feedback systems

Closed-loop drive systems operate by attempting to reduce to zero the difference between the speed reference signal and the feedback signal. Thus if a feedback device fails or becomes disconnected, the output of the drive becomes large and uncontrolled. The most vulnerable of feedback devices is usually the speed sensing device, which is often duplicated for additional security. Monitoring circuits built into the drive compare the difference signals between the outputs of the two sensors and the speed reference. Figure 7.4 shows such a system applied to a static converter drive. The motor armature current feedback is monitored separately.

Protection against failure of feedback systems must be built into all closed loop drive systems. The protection must be fast acting and stop the lift immediately.

7.4.4 DC motor control techniques

DC gearless machines are still the most common type of drive for lift speeds greater than 2 m/s. There are two basic methods of controlling DC motors: the Ward Leonard set and the static converter drive. Static converter drives are the most economical in operation with energy costs up to 60% less than those for equivalent Ward Leonard drives.

7.4.4.1 Ward Leonard set

A Ward Leonard set[7] is an AC motor driving a DC generator using a mechanical coupling, see Figure 7.5. Open loop control, i.e. no feedback of the motor speed to the control device, or simple armature voltage control allows tolerable performance over a 30:1 speed range. Speed control is obtained by switching resistances in series with the generator field. Careful adjustment of series field windings in the machines is necessary to equalise the up and down direction speeds. The dynamic characteristics of circuits of this type are not stable, both over time or temperature, which generally appears as variations in the slow speed approach to floor level.

Surveys carried out prior to modernisation show that many generators are too small for the rated load and speed. Consequently, such lifts usually run slower than specified and the transportation capacity is restricted. The solution is either to install a larger generator or to fit a static converter, see section 7.4.4.2.

The best control for generators is achieved by using feedback techniques to regulate the motor speed, armature current and the generator field current, see Figure 7.6. This reduces the energy losses in the generator by at least 20%, and reduces the current peaks in the machines. The control of armature current ensures a stable drive, which does not drift with time and temperature. Within the limits of the generator capacity, the ride performance of the lift is as good as that using static converter drive.

The generator requires regular maintenance to maintain it in good condition. The accumulation of carbon dust from the brushes can cause earth leakage currents. Incorrect brush pressure, material and brush gear settings cause scoring of the commutator and consequent sparking leading to rapid deterioration of the machine. Undersized generators and poor control cause overheating of the machine, thus shortening the life of the insulation.

7.4.4.2 Static converter drives

A static converter is an electronically controlled power converter which converts AC to DC and inverts DC to AC. Used with a DC motor, static converters provide high efficiency and accurate speed control without the use of a DC generator. The power losses are very low, typically less than 5%.

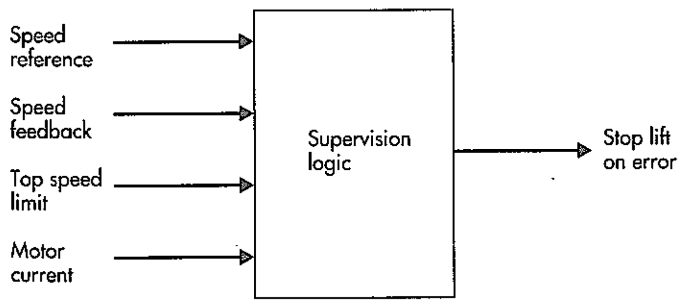

Figure 7.4 Supervision logic for closed-loop drive

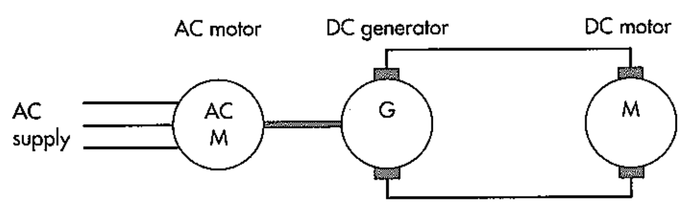

Figure 7.5 Ward Leonard set

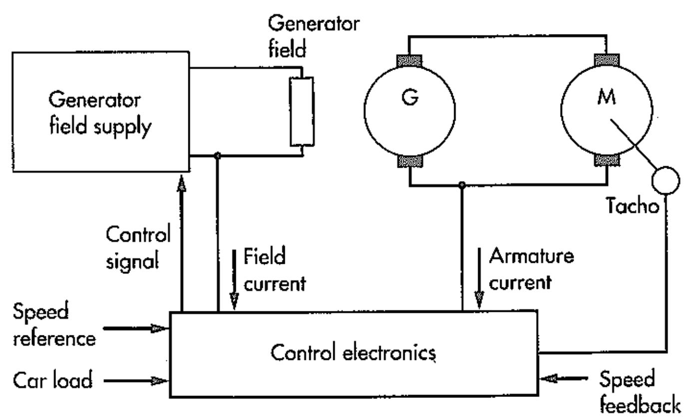

Figure 7.6 Generator control using feedback techniques

Lifts require a smooth, linear reversal of motor torque to obtain a good ride. The majority of drives designed for industrial use cannot reverse motor torque with the smoothness required for lifts. Hence, purpose-designed drives are preferred.

Power conversion is accomplished using bridges of thyristors or silicon controlled rectifiers (see section 7.4.5). Using phase control, the DC output of the bridge can be varied from zero to full power, in order to drive the motor.

Static converters enable the kinetic energy of the lift to be returned to the mains supply by the process of inversion. When the motor voltage is higher than the supply, energy can be returned to the mains by suitably controlling the conduction angle of the bridge thyristors.

A detailed description of the characteristics of the basic types of thyristor bridges is given in Davis[8]. The waveform of the current drawn from the supply to a static converter is substantially a square wave. This produces harmonic currents in the supply which interact with the supply impedance to produce voltage distortion. The Electricity Association's *Engineering Recommendation G5/3*[9] gives the allowable limits for the magnitude of the individual current harmonics and the voltage distortion produced. Note that AC drives also produce harmonic currents.

The harmonic current levels generated by the basic three-phase bridge (6-pulse bridge) can be reduced by using two bridges in series or parallel (12-pulse bridge).

The 12-pulse bridge construction is more expensive and has latterly not been economically viable for lift control.

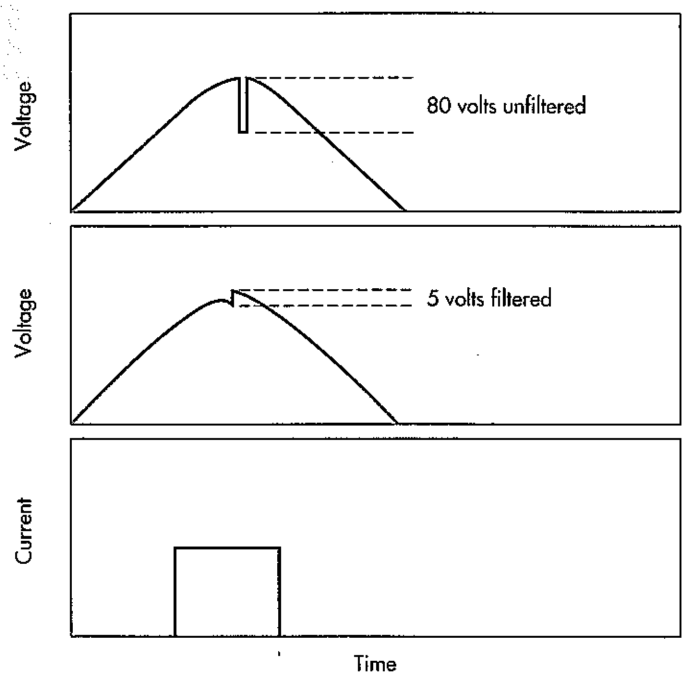

Figure 7.7 Effect on supply voltage of filtered and unfiltered static converters

Input filters must be used both to protect the thyristors from damage during switching and to function as voltage disturbance and harmonic attenuators. All controlled drives using switching devices produce short duration voltage disturbances to the supply.

The input impedance of the static converter should be at least 10 times the supply impedance to the lift installation. The input filter inductors should ideally be air cored to maintain the inductance value under all possible operating conditions of the drive. In contrast, iron cored inductors suffer from loss of inductance under high and fault current conditions. Figure 7.7 shows the typical effect on the supply voltage of filtered and unfiltered static converters.

Filters should also be used on the output. Three phase six-pulse DC bridges produce a 300 Hz AC ripple on the DC output when supplied from a 50 Hz mains. Without filtering, the ripple amplitude is approximately 4% of the DC output.

The lift motor will produce substantial audible noise at the ripple frequency, if there are no output filters. This noise is obtrusive and easily transmitted into the building via the structure and the lift well. Output filters can reduce the ripple by a factor of 10.

All static converters should have built-in protection for current overload and supply failure. Ideally, this should not rely on high speed semiconductor fuses or circuit breakers for the first line of protection. Semiconductor fuses deteriorate with age and can often be the source of unnecessary lift breakdowns. For maximum reliability, the first line of overload protection should be electronic.

The drive, in conjunction with the lift controller, should be capable of automatic return to operation after a mains supply failure. It should be able to tolerate repeated mains supply disconnection, when the lift is running at contract speed.

There are two basic types of static converter drive suitable for use with lift motors. These are classified by the number of bridges used to supply the motor armature, i.e.:

— single bridge with motor field control
— two bridge with fixed motor field.

Both types should use a distance-based speed reference to obtain maximum electrical efficiency and lift transportation capacity.

7.4.4.3 Single bridge static converter with motor field control

This system is used in an attempt to save the high costs associated with the large thyristors used to supply the motor armature. Figure 7.8 shows a schematic diagram of the system.

A single thyristor bridge is used for the conversion of power to supply the motor armature. The motor field is controlled to reverse the power flow, motor torque and

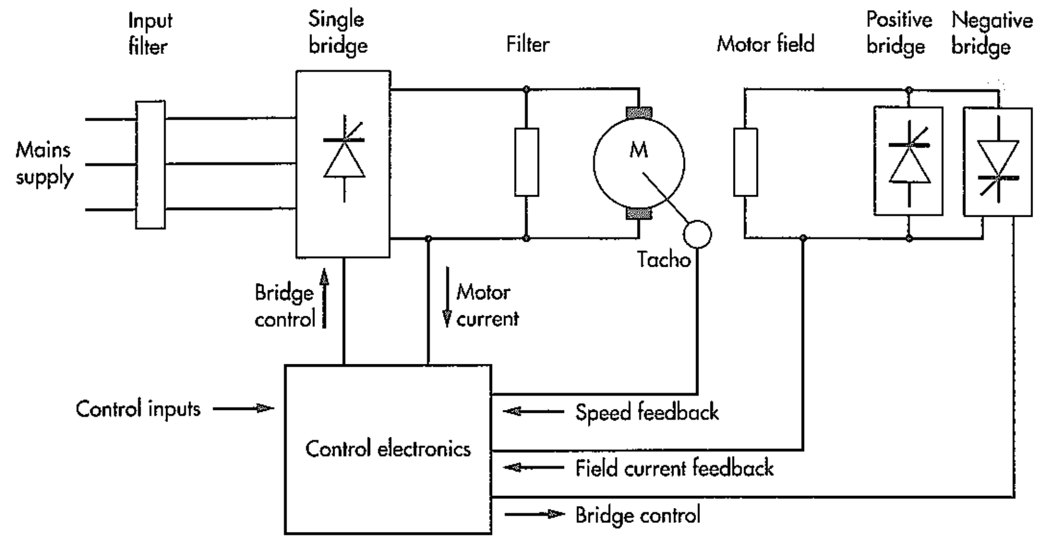

Figure 7.8 Schematic of single bridge static converter with motor field control

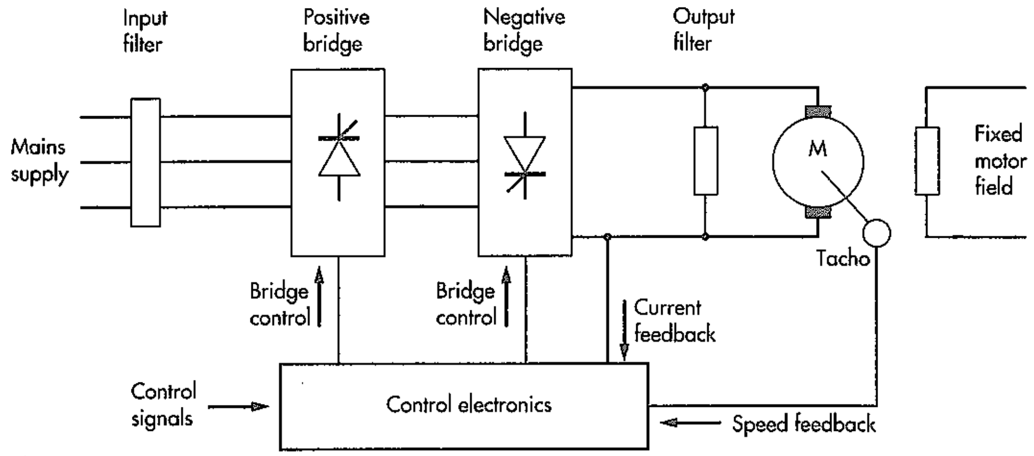

Figure 7.9 Schematic of two-bridge static converter with fixed motor field

direction of rotation. Two low-power thyristor bridges are used to supply a variable polarity and magnitude current to the motor field.

Although cheaper to build than two-bridge drives, there are some significant disadvantages with the single bridge approach. First, the control circuit is complex since it is required to control three thyristor bridges. Secondly, field control depends on the motor characteristics, which vary with type and manufacturer. Consequently, it is difficult to design the control circuits to compensate accurately for all motor types. The control of the motor, therefore, may not be sufficiently stable with time and car load over the speed range of the motor.

7.4.4.4 Two-bridge static converter with fixed motor field

Figure 7.9 shows a block diagram of the most common type of two-bridge static converter. The motor field is supplied from a constant voltage supply, set at the nominal value for the motor. Some types of gearless motor require a reduced field current to achieve rated speed, the field current being higher during acceleration and deceleration. This is the only variation of the motor field, which may occur while the lift is running.

This system does not depend on motor field current or armature characteristics and a standard design can be used for all types of motor. Using current control, the drive is stable with time, temperature and mains fluctuations.

7.4.5 AC motor control techniques

The AC variable voltage drive is the most cost effective drive for lift speeds up to 2 m/s. For speeds of 1 m/s or less, and small lift cars (i.e. less than 8 persons), a simple AC drive without relevelling may be satisfactory. A drive with relevelling should always be specified for larger lift cars and higher speed applications or where small wheeled trolleys etc. may be used.

Variable voltage, variable frequency drives provide the best all-round drive performance for lift speeds from 1.6 m/s upwards. They give near unity power factor operation and draw lower acceleration currents (e.g. twice the full load current) requiring smaller mains feeders. Provided that it is correctly designed and filtered, the variable voltage, variable frequency drive produces the lowest harmonic current and voltage values in the supply of all the various types of solid-state drive.

7.4.5.1 Variable voltage drive with single-speed motor

There are several variations using the variable voltage technique, depending on whether the speed of the motor is controlled during all phases of the lift movement.

For low-speed, low-grade lifts (e.g. car park lifts and goods lifts) it is possible to obtain accurate and consistent stopping at floor level by controlling only the deceleration of the lift. This technique is suitable for lift speeds up to 1 m/s. Some drives of this type do not allow relevelling.

Thyristors can be used to control the acceleration of the lift. They also reduce the voltage on the motor during deceleration and can be controlled to produce DC to obtain more braking torque if necessary. This technique is also suitable for lift speeds up to 1 m/s.

Thyristors can be used to control both the acceleration and deceleration of the lift by reversing the phase rotation of the supply. Due to the lower efficiency of AC phase rotation reversal for braking, the design of the control for the thyristors is critical to obtain good jerk-free torque reversal of the motor. This technique also increases motor and machine room heating compared with DC braking. This technique is suitable for lift speeds up to 1.6 m/s.

7.4.5.2 Variable voltage drive with two-speed motor

In general, the low-speed windings of the motor are used as braking torque windings. The AC supply voltage to the high-speed windings is controlled using phase control by means of thyristors. The speed of the motor is under control at all times during movement of the lift. The starting current of the motor is reduced to approximately 50% of the current drawn by the same motor running as a an uncontrolled two-speed motor. During deceleration, the AC voltage is reduced and a variable DC voltage is applied to the low-speed winding to produce additional braking torque if necessary.

Some drives of this type limit the maximum speed of the motor to approximately 90–95% of its full load maximum speed. This is because the speed reference and deceleration control cannot deal with variations in the rated speed of the motor due to the load and bring the lift to a halt accordingly at floor level under such circumstances. The electrical efficiency of these drives is considerably reduced and heat losses are increased by limiting the top speed. The motor is working with large slip and DC power has to be applied to the low-speed winding to maintain motor control. Additionally the traffic handling capacity of the lift is unnecessarily reduced.

All drives of this type should have relevelling and levelling accuracy of at least ± 5mm under all load conditions and are suitable for lift speeds from 1.0 to 2.0 m/s.

The ride comfort, levelling accuracy and traffic handling achieved using two-speed motors can be easily improved by using an electronic drive. Electronic drives are used for speeds up to 1 m/s. The peak starting currents are higher for two-speed drives. However, in low traffic situations and for some goods lifts, the extra costs of electronic drives may not be warranted.

7.4.5.3 Variable frequency drives

Variable frequency drives use the fundamental characteristic of the AC induction motor, i.e. that its synchronous top speed is proportional to the supply frequency. By varying the supply frequency the motor can be made to function at its most efficient operating point over a wide speed range. However, the conversion of power at a frequency of 50 Hz to power at a variable frequency suitable for the motor is a complex process.

These drives provide a high power factor (i.e. >0.9) at all lift speeds and with low electricity and machine room cooling costs.

Variable frequency drives need only a single speed motor. Where existing lifts are being modernised, the drive may be fitted to an existing single or 2-speed motor. In such cases, the lift manufacturer must always be consulted to determine the suitability of retaining the existing motor for use with a variable frequency drive.

For lift speeds up to 2 m/s, using gearboxes, the energy regenerated by the lift is relatively small and can normally be dissipated by a resistor. The cost of a 4-quadrant drive to regenerate power to the mains is usually not warranted.

Lifts capable of speeds up to 5 m/s are currently being installed using AC gearless motors, and still higher speeds are possible. In these circumstances a 4-quadrant drive is usual, regenerating energy to the mains supply, rather than dissipating it by means of a resistor.

7.4.6 Control of hydraulic drives

7.4.6.1 Control valves

Hydraulic valves produced in the early 1970s were generally not very well compensated for control variations with car load, oil viscosity and temperature. Consequently the levelling accuracy and lift speed varied according to the load.

Many modern control valve designs are fully compensated for pressure and viscosity variations and therefore provide stable characteristics over long periods. This allows higher lift speeds (i.e. up to 1 m/s) with accurate levelling and short levelling times.

The flow of oil is controlled either by internal hydraulic feedback (pilot valve) or by electronic sensing of the oil flow. Electronically controlled valves use proportional solenoids to control the oil flow. Electronically controlled valves are more efficient than hydraulic feedback types when operating at extremes of oil temperature.

7.4.6.2 Speed control

The pump motor runs only when the lift travels upwards and the pump has to lift the entire load when a counterweight is not used. The motor power is therefore approximately twice that of an equivalent electric traction lift. Star-delta starting is generally employed to prevent large acceleration currents. Usually, the motor runs at a constant speed. The oil pressure and flow to the hydraulic ram is controlled by returning oil direct to the tank, bypassing the jack.

When the lift runs downwards, the control valve is opened and the lift car makes a controlled descent under the effect of gravity. The up and down speeds are generally independently adjustable on the valve block. The down speed can be higher than the up speed. This allows the average lift velocity to be higher than that provided by the pump. This reduces the round trip time of the lift and increases the traffic handling capability, see section 3.

Valves are rated by oil flow rate (litre/minute) and maximum top speed. Electronically controlled valves are suitable for speeds up to 1 m/s. Hydraulic feedback valves are more suited to lower speed applications, i.e. up to 0.75 m/s.

7.4.6.3 Anti-creep devices

BS 5655: Part 2[(2)] specifies the use of some form of anti-creep device on all hydraulic lifts. This is a safety measure to prevent the lift sinking down from floor level due to oil leakage. The anti-creep action may be 'active' whereby the lift is driven up if the lift sinks below floor level due to leakage or oil compression when a heavy load is placed in the car.

For large goods and vehicle lifts, the lift can be physically held at floor level using mechanical stops in the lift well. This is more complicated, both mechanically and electrically, but provides a better solution for these applications than active relevelling.

7.5 Control of door operators

7.5.1 General

The door operator, see section 6.7, and its control system must meet the following requirements:

— the opening and closing speeds must be independently adjustable

— for high-performance lifts, the opening and closing speeds must be automatically adjustable according to the prevailing traffic conditions at the floor

— safety edges must be fast acting and tolerant of mechanical impact; remote sensing edges (i.e. electronic) are inherently better than mechanical edges in these respects.

Light ray (i.e. photocell) or other passenger/object detection devices may be used to modify door control. Additionally, they can be used in conjunction with a load sensor to prevent nuisance car calls.

Advanced opening is a time-saving feature widely used in office buildings to improve performance, see section 3.6.4. This allows the doors to commence opening once the car speed is below 0.3 m/s and the lift is within the door zone (typically ± 100 mm, maximum ± 200 mm). However, it can be disturbing to elderly users and may not be suitable in some buildings.

7.5.2 Control of DC door operators

Two methods have been in use for many years:

— resistance control of motor field and armature

— saturable reactor control.

These methods control the door velocity depending on the position of the doors in relation to the open and closed positions. DC motors are often provided with additional velocity control to provide a smooth stop at the extremes of travel of the doors.

Position sensing is normally by limit switches. It is difficult, and almost impossible economically, to vary the door speeds in response to prevailing lift traffic conditions using commands from the controller. This is a major limitation to obtaining maximum handling efficiency in large lift groups with heavy traffic.

Some manufacturers have introduced electronic speed control of the motor. Control of deceleration is by limit switches. The speed reference is usually time-based. This removes the need for banks of resistors and makes the door operator easier to set up, the electronics merely replacing the resistors. Unfortunately many of these operators still retain sinusoidal mechanical linkages, see section 6.7.2. It is important to ensure that the operator mechanism is suitable if a drive of this type is offered.

7.5.3 Control of AC door operators

Simple AC door operators do not have speed control, and the motor runs at a constant speed. The door motor may be designed to run safely, when stalled with the full supply voltage applied. Constant speed door operation is suitable for narrow doors and where traffic is low so that the limited speed does not restrict lift performance.

7.5.4 Electronic control of AC door operators

AC variable voltage door operators typically use a single speed motor. Braking torque and direction is controlled by reversing the phase rotation of the supply. This technique is satisfactory with low-power motors.

The speed, position of the doors and motor torque can be controlled using closed-loop feedback. The feedback signals are monitored and compared with reference signals. If there is loss of, or large errors in, the feedback signal the door drive is stopped.

Logic circuits built into the door operator control the speed reference so that the doors always follow a distance-based velocity curve. This safely minimises opening and closing times and prevents high acceleration forces on the doors.

Logic circuits can also control the reopening of the door in response to safety signals. For example on a 1200 mm entrance, the doors open only to 800 mm in response to the first reopen signal. This minimises the door operation time to maintain the maximum possible traffic handling capability. Additionally, the lift controller can, as an option, modify the door speeds and open times in response to changes in the level of traffic.

Good electronic controlled operators, using velocity and position closed-loop control, are suitable for both general use and for demanding applications. In modernising a lift system, electronic operators, used in conjunction with good group control and lift motor control, can produce dramatic increases in the traffic handling capacity of the lift group (typically 30–40% improvement).

7.6 Group control

7.6.1 General

The function of efficiently distributing landing calls to individual lift cars in a group is basically the same for both large and small groups. Thus, a two-car lift group can benefit from the use of group control as much as an eight-car group.

The distribution of landing calls is handled by a relay-based, solid-state or computer-based group controller. For a given group of lifts, computer-based group control, using a correctly designed group control algorithm, will outperform a 'non-intelligent' system under all circumstances. However, even if a good computer system is used, the size of the lift group must be the right size for the building, population and use.

Having determined the group size (see section 3) and group control system, a comparison of the effectiveness of the group control system can be obtained from the predicted performance for up-peak, down-peak and interfloor traffic. This appears as a difference in interval times (see sections 3.5 and 3.10) for different control systems. (Note that the same drive and door parameters, e.g. speed, number of cars, etc., must be used in comparing different control systems.)

The major lift companies and lift consultants have developed computer-based lift planning and traffic calculation programs, see section 11, which can achieve some or all of the following:

- select a suitable lift group, given the building size, use and population
- determine the performance of an existing lift group within a building
- predict the performance of an existing group of lifts if the control system, drive or doors are replaced.

The use of on-site measurements and the calculation of performance levels with new equipment allows the building owner and user to appraise the benefits of new equipment before an order is placed.

7.6.2 Landing call collection methods

7.6.2.1 Automatic push button (APB)

Only one landing call at a time is accepted by the controller. When a car call is present, no landing calls are accepted.

This non-collective method is suitable for very small lifts (i.e. up to six persons) in low-rise residential blocks of up to three storeys, where it gives users a measure of security. It is also suitable for goods lifts with manual doors.

To avoid user frustration, a 'Lift busy' indicator should be positioned adjacent to each landing call station to indicate that the lift cannot accept landing calls.

7.6.2.2 Non-directional collective control (single call button per landing)

A single landing call button registers a call which the lift will answer regardless of the direction of travel of the lift at the time of the call. If the lift is travelling in the opposite direction to that required by the passenger, the passenger can either travel with the lift or wait until the lift returns having completed its travel in the opposite direction (a new call must be registered to stop the lift).

This system is economical in terms of components but there is a high probability of long waiting times for lift users and the traffic handling capacity is low. With the use of computer-based and solid-state controllers, the cost saving is minimal and the disadvantages outweigh the cost savings.

7.6.2.3 Down-collective control or up-distributive/down-collective control (single call button per landing)

All landing calls are registered by the lift controller as down calls at all floors except the ground floor where a call is registered as an up call. They are assigned to the lift as it moves from top to bottom of the building. If the lift is idle or parked at the bottom of the building, when several landing calls are placed, it drives to the uppermost call first ('high call reversal').

Down collective control is suitable for buildings where little or no interfloor traffic is present, e.g. car parks or residential buildings. It is not suitable for office buildings or hotels.

7.6.2.4 Full collective control (two call buttons per landing)

Up and down landing calls are registered separately. The lift stops to answer calls in its present direction of travel only, calls in the opposite direction being answered when it has completed its travel in the present direction or if the car becomes idle.

Full collective control is the most efficient of the above methods for moving people around the building. This form of control is essential in commercial buildings to maximise the efficiency of the lift in handling interfloor and directional peak traffic. However, a problem with this system is that many users misunderstand the control system and push both buttons, thereby increasing the number of stops made by the lift.

7.6.3 Peak traffic detection

The major problem in group control is detecting peak traffic at specific floors and at different times of the day. If the group control does not respond correctly, peak traffic can rapidly overload the lifts causing extremely long waiting times. Peak traffic can be directional (i.e. into or out of the building), interfloor or a mixture of the two. Traffic peaks can occur at any time of the day.

Until the 1980s, office working hours were relatively stable. Incoming and outgoing traffic peaks could be predicted and simple time clocks used to switch the mode of operation of the group control. The installation of analogue computer circuits to measure the numbers and direction of landing calls provided additional discrimination.

Changes in working practices to more flexible and staggered office hours defeat these simple strategies for handling peak traffic. To compound the problem, building population densities have often increased beyond the original designed capacity of the lifts using non-computer-based systems.

7.6.4 Parking sectors

The group control equipment may divide the building into sectors and ensures that at least one lift is parked in each sector, when there is no traffic demand to be served. When traffic is present and there is no car available in a particular sector, a car may be returned to that sector as soon as one becomes idle.

The system is wasteful of energy, owing to unnecessary lift movement and changes in floor usage can result in poor service and long waiting times at some floors. It may be better to define the main terminal only as a parking floor and leave all other lifts at their last stopping floor.

7.6.5 Reliability

The logic circuitry for this type of equipment is complex. Lift service engineers may not notice faults, leading to a gradual deterioration in the quality of service. In surveys prior to modernisation, many lifts using relay-based equipment show long waiting times and a large distribution of waiting times.

In relay-based group control, the landing calls are not connected directly to the individual lift controllers and failure of the group controller (e.g. by loss of its power supply) can cause total loss of the lift service in the building. Unlike computer-based group controllers, it is not practical to provide a backup group control with these types of system (see also sections 7.3.2 and 7.3.3).

7.6.6 Non-computer-based systems

Relay and 'non-intelligent' solid-state systems are not recommended for any situations other than those having very low traffic densities (see section 7.3). It is expensive and difficult or, for some features, impossible to ensure that such systems respond correctly to changes in the building traffic throughout the day. Furthermore, they cannot accommodate changes in building use, and their use often leads to poor lift performance, long passenger waiting times and the formation of queues. However, solid-state systems are reliable and can perform satisfactorily in light duty duplex (two-car) lift groups. For all other traffic situations, computer-based control systems should be specified (see section 7.6.7).

7.6.7 Computer-based systems

Computers allow raw data to be collected from the system for processing to enable sophisticated approaches to group control. This allows fast, flexible and adaptive responses to traffic situations in the building. Correctly designed algorithms can adapt to changes in use of floors, building and population without the need for modifications by the manufacturer.

The computer can process the following information which can be available as inputs to provide optimal group control for the lifts.

Operational information for each lift, as follows:

- operational mode (in or out of the group)
- running state (moving or stationary)
- position
- planned or actual direction of movement
- if stationary, door status (opening, open, closing, closed)
- number of car calls
- car load
- rated speed of the lift (some manufacturers can mix lift speeds in the group)
- current system response time to each landing call (time to travel to that landing).

Landing information, as follows:

- number and direction of landing calls
- waiting time of each landing call
- computed traffic intensity at each floor.

Group information, as follows:

- measured maximum landing call waiting times.
- measured average landing call waiting times.

7.6.8 Traffic control algorithms

7.6.8.1 General

There are many different algorithms for group control, all of which attempt to optimise the performance of the lift group under all traffic and group conditions.

The computer allows traffic handling performance to be measured easily. This information can be used to optimise the distribution of the landing calls to the individual cars.

In Figure 7.10, curve (a) shows the probable distribution of landing call waiting times for an ideal group control system. The distribution is rectangular and all calls are answered in less than 30 seconds. For practical systems, the curve tends towards a normal distribution, centred on the average waiting time. Curve (b) shows the distribution typical of good computer-based group control. Curve (c) shows a distribution typical of relay-based group controllers. There is a higher probability of very long waiting times when relay-based group control is used.

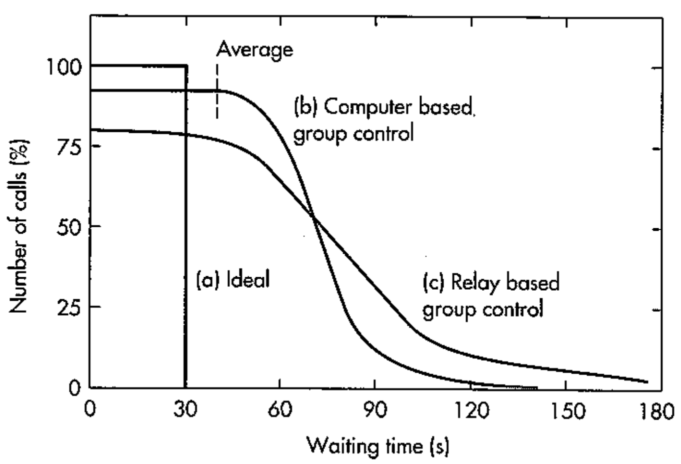

Figure 7.10 Distribution of landing call waiting times

Minimisation of average landing call waiting times and reducing the number of calls with very long waiting times shows that the group control is functioning well.

Figure 7.11 shows that, for low traffic conditions, both relay and computer-based types of group control perform well. As the traffic level rises towards the design maxima for the group, the probability of long waiting times increases. Above the design maxima, relay-based systems quickly lead to extremely long waiting times whereas good computer-based systems show a more gradual deterioration in performance.

Some computers allow the parameters to be adjusted to fine-tune the group control to the building. This allows modifications on site without expensive and time consuming changes to the operating software.

7.6.8.2 Non-computer-based algorithms

There are four basic types of traffic control algorithm which allocate landing calls to cars.

- Nearest car: the 'nearest car' is allocated to each landing call. A set of rules determines the suitability of each car to handle a particular landing call. For example, the nearest car travelling in the opposite direction may not be so suitable as another, less near car which is travelling in the required direction. This algorithm is suitable for simple applications such as car parks and low-rise office buildings.

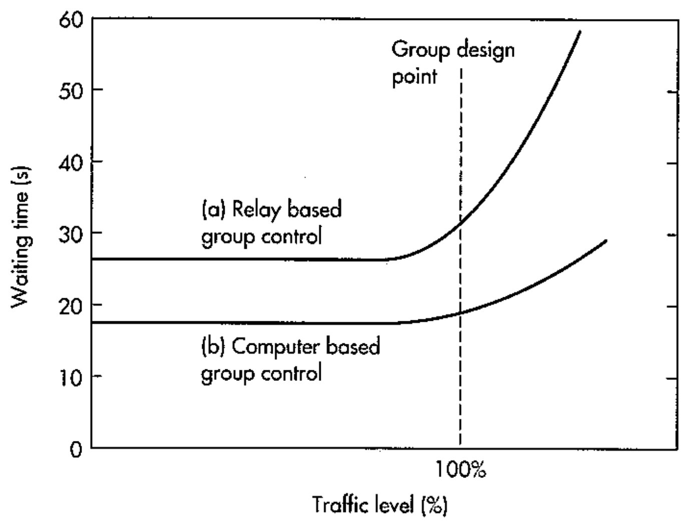

Figure 7.11 Variation of performance of group control with traffic level

- Fixed bi-sectional sectors: the building zone to be served by a group of lifts is divided into as many sectors as there are lifts in the group. A car present in a particular sector collects all the landing calls in that sector. In practice, the allocation of calls is determined by complex rules. This algorithm is suitable for groups of three to eight cars in office buildings.
- Fixed unidirectional sectors: the building zone is divided into a number of fixed up and down sectors according to the number of cars in the group. The sectors may not be coincident and a duration timer may be included to allow the allocation of a free car to a long-wait sector. Complex rules assist in the allocation of calls. This algorithm is suitable for groups of three to eight cars in office buildings.
- Dynamic sectors: the position of the cars determine the boundaries of each sector. Thus, as the cars move, the boundaries of the sectors change. A second algorithm introduces free cars ahead of cars with a higher than average number of calls (i.e. car plus landing) to serve. This algorithm is suitable for groups of three to eight cars in office buildings.

7.6.8.3 Computer-based algorithms

There are three basic algorithms for computer-based traffic control.

- Estimated time of arrival (ETA): landing calls are allocated to cars on the basis of the shortest time to arrive at the landing. The algorithm takes account of all existing car and landing calls. The computer program modifies the process to deal with floors with particularly heavy duty, long-wait calls, priority calls etc. This algorithm is suitable for groups of three to eight cars in office buildings.
- Self-tuning systems: such systems include computer software which 'tunes' the algorithm to various parameters (e.g. shortest passenger waiting time, longest passenger waiting time etc.) in order to respond to changes in traffic demand, average system response time etc. This algorithm is suitable for groups of three to eight cars in office buildings.
- Hall call allocation: systems using this algorithm require the passengers to register their destinations on a special panel before entering the car, after which they are directed to a suitable car. Therefore the control algorithm has additional information to process. This algorithm is suitable for groups of three to eight cars in office buildings where there is little or no public access.

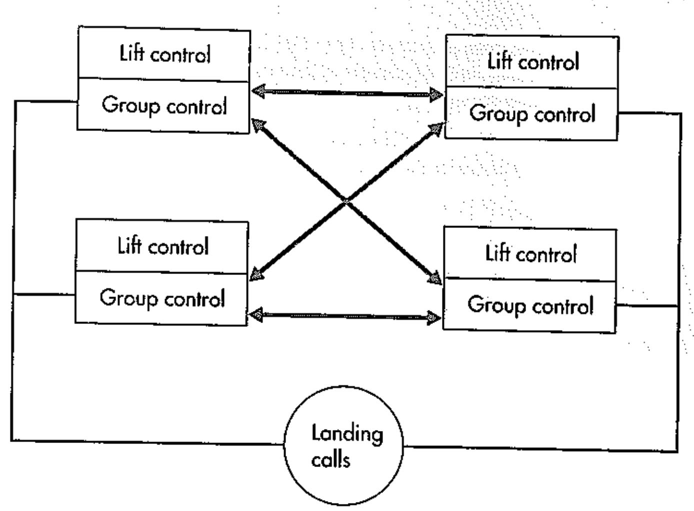

Figure 7.12 Multiple group control capability

7.6.9 Group control backup

With computer-based systems it is easy to provide backup to normal operation to accommodate failures in the controller which could otherwise cause complete loss of lift service.

The first level of group control backup, however, should not be a 'bus stop service' in which landing calls are ignored and the lifts move continuously between floors, stopping at each floor to pick up any waiting passengers. Backup service of this kind is electrically inefficient and gives very poor lift service to the building.

Using high-speed communications channels between computers, redundancy can be built into a group control to provide backup. Many approaches are possible. Two computers connected together can be used to control a group. Either computer can control the group, but only one runs the group control at any one time. The second computer monitors the operation of the first. Should the first computer fail, the second reports the failure and takes over the group control.

Computers capable of providing both individual lift control and group control can be used, see Figure 7.12. For example, on a four-car group this means that there are four computers able to run the group controller. If the computer currently running the group control fails, one of the other computers automatically takes over. Even if all the group control programs were out of action the lift control could still perform a basic collective operation in response to the calls because the landing calls are registered by each lift computer. In practice, this means that group control reliability is very close to 100%.

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8 Electrical systems

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Contents

8 Electrical systems

8.1 Introduction

The provision of power supplies and electrical systems for lifts must be considered in relation not only to the power supplies for the whole building but also to other electrical systems which may interact with the lift installation. In all buildings, the power supply and electrical systems should be fully integrated so as to serve the demands of the building as a whole. Failure to consider the complete lift installation as an integral part of this system can result in an unsatisfactory lift service for the entire life of the building.

8.2 Power supplies

8.2.1 General

A series of questions needs to be considered to determine how and why power supplies are required to meet the lift demands, followed by further questions to clarify how these requirements will be met in terms of power distribution hardware and its installation. The lift power supplies form part of a more extensive power distribution system and the power requirements of the lifts must be considered in relation to the other users of the system.

In addition, the potential operating modes of the power distribution system and the building usage patterns should be investigated to determine how the services in the building are expected to perform when:

— the building is normally occupied

— the building is partially occupied

— the mains power fails

— systems fail or system faults are experienced.

Check lists can be drawn up for the lift installation with cross-references to associated services, see Tables 8.1 to 8.3. This information should be given to all parties involved in specifying and designing the finishes and services for the building. At each interface it should be made clear who is responsible for designing and supplying the relevant equipment and systems. It must also be agreed what facilities are considered essential.

The type of lift drive and associated control equipment will influence the design of the power supply system in terms of the cable distribution requirements, back-up supplies and with respect to the problems of harmonic currents drawn by the lift equipment, see section 8.4. The design must result in adequately rated supplies to meet all operational demands, including meeting maximum power demands for simultaneous starting and braking of lift cars.

8.2.2 Protection of supplies

Lifts must be protected against malfunction in the event of the following electrical faults in the power supply feeding the lift installation.

8.2.2.1 Absence of voltage

Loss of voltage may be due to a system fault where power has been isolated by the operation of a protective device or due to loss of mains supply.

On restoring power, the lift should be returned to service automatically. Therefore, the lift controller must ensure that normal controls and safety devices function correctly when power is restored.

8.2.2.2 Voltage drop

A drop in voltage may be caused off the site by a weak supply (i.e. high impedance source) and/or a particular mode of operation of plant and equipment in the building. Such conditions may exist when many independent loads switch on at the same time. Table 8.4 provides a checklist to help determine the cause. If the power distribution system for the building is incorrectly designed, the problem may occur every time there is multiple switching of loads. When correctly designed, the power supply to the lift installation should not suffer a drop in voltage outside the limits agreed with the lift designer for all modes of operation of all of the services in the building.

8.2.2.3 Loss of a phase

Loss of continuity of a conductor or loss of a phase can be the result of a broken conductor or the operation of a single fuse. The lift control equipment will detect this condition and shut down. Normal operation can be resumed when the three-phase supply is restored and any lift control and/or motor protection has been reset.

8.2.3 Standby power

In many buildings, particularly large ones, standby power supplies are installed to allow some or all of the normal activities of the building to continue and to ensure that the building can be evacuated safely[2]. The cost of

Table 8.1 Typical schedule for electrical system requirements — machine room

System	Requirements	Interface and notes
Power supply for lifts	Single main for firefighting lift	Supply monitored by building management system (BMS)
	Single main for each lift or a single supply to feed each group of lifts	Supply monitored by BMS
	Single main for lift well and machine room power and lighting	Supply monitored by BMS
Power for lift machine room	Small power socket outlets	See *BS 5655*[1]
	Lighting	
	Lift well lights	
	Lift car lights	Prominent means of isolation
	Lift car (top) maintenance socket outlet	Prominent means of isolation
Environmental control	Heating	May be linked to central controls
	Ventilation	May be linked to central controls
Earthing and bonding	All metal work to be bonded and connected to machine room earth bar	Separate machine room earth bar cabled to main building earth
Fire detection and alarm	Smoke, rate of rise detectors, manual break-glass stations and sounders	Integrated with main building fire alarm system
Communications	Car intercom	Linked to internal building intercom system
	External communications (telephone)	Emergency dial-out feature through public network. Where this may be abused the dial-out may be barred to a single number or routed through the main reception or security desk serving the building
	Automatic dial-out	Where remote monitoring of the lift installation for performance and/or alarms is required, an automatic dial-out facility will be necessary using the public network
Monitoring and controls	Control for reduced lift service (i.e. reduced speed and acceleration when power is limited)	Signal from standby power supply to prevent simultaneous starting and overload, reduce speed and acceleration or other means to limit the lift load current
	Status indication and alarms	Interface to BMS and automatic call-out for maintenance

Table 8.2 Typical schedule for electrical system requirements — lift car

System	Requirements	Interface and notes
Lighting†	Normal and emergency lighting	Emergency standby battery system (specify minimum lighting levels required)
Controls†	Car destination controls	Operation through the lift controller. Is 'key holder' override required?
	Door hold controls	
	Alarm control	
	Maintenance controls (on car top)	Maintenance switch and push
Indication†	Position	Operation through lift controller
	Selected floor	Operation through lift controller
	Overload/car out of service	Operation through lift controller
Communication	Emergency bell	Remote sounder — off-site
	Intercom	Machine room and building system
	Telephone	Connected to external telephone line — single number auto-dial
	Audio system	Building or lift PA system
Ventilation	Forced ventilation if required	
Power	Maintenance power outlet on car top	

† These items interface with requirements for special finishes and decor.

Table 8.3 Typical schedule for electrical system requirements — lift well

System	Requirements	Interface and notes
Lighting	Permanent well lighting	Controlled from machine room and/or pit with warning pilot light
Power	Socket outlet in lift pit	See *BS 5655*[1]
Earthing and bonding	Guide rails and metal landing door surrounds bonded to earth	Connect to building earth system
Heating	Provided if necessary	Automatic controls or connection to central system
Monitors	Pit water flood detector if necessary	Remote alarm

Table 8.4 Typical schedule for voltage drop checks

Item	Check required	Comments
1	Reliability of external supply	If supply is subject to voltage fluctuations consider the installation of a voltage stabiliser to feed the lift
2	Operation of other loads on the the power distribution system†	Carry out load flow study
3	Operation of other independent loads†	Consider interlocked or sequential starting controls
4	Volt drop on lift feeder cables†	Size cables to ensure that under the worst operating conditions the voltage drop is always within limits agreed with the lift designer

† May require dynamic load flow study of the power distribution system.

providing a standby supply is usually high in relation to its expected operating life. The tendency, therefore, is to keep the standby capacity to a minimum to meet only essential loads.

Essential loads may include firefighting plant, partial or full lighting, consumer power supplies, computer power supplies, lifts, HVAC plant etc. The requirements for standby power will depend, therefore, on which of the services are to remain partially or fully operational during a mains failure.

The load to be imposed on the standby power plant will also vary, depending on when it is called upon to operate, i.e. night or day or winter or summer. It will also vary with any changes of building use. The standby supply must be able to meet all the demands of the dynamic loads (electrical) of the complete distribution system. The general design considerations noted in section 8.2 apply. In addition the following must be provided:

- controlled sequential starting systems for other loads, if necessary
- a limited or special-purpose mode of operation of the lifts (if a full service is not required)
- controls for sequential starting of the lifts to limit power demand surges
- effect of lift braking on power demands
- sufficient capacity to absorb regenerative braking or prevent overspeed of the lifts when fully loaded.

Any operational restrictions imposed by the lift installation when operating under standby power must be clearly identified. All necessary automatic or hand controls, indications of system configuration and mode of operation, and alarms must also be included in such identification.

8.2.4 Isolation

Suitable means of isolating the power supplies must be provided in the lift machine room. Additional means of isolation, in the form of a stay-put (stop) button, must be provided in the following locations:

- adjacent to the lift motor if direct access to main isolator is not possible
- on the top of the lift car (part of the maintenance controls)
- at the bottom of the lift well.

The device used for mains isolation in the machine room must be of a type which can be padlocked in the 'off' position.

It is not good practice for the machine room mains isolation device to include protective equipment (i.e. fuses or circuit breakers). Such protection should be located at the point where the main supply feeds the lifts. This may be the main switchboard where each lift has a separate feeder or at the distribution switchboard where one main feeder serves more than one lift. The lift manufacturer must provide suitable protection for the lift controller. All such protection devices must be coordinated to ensure proper fault clearance discrimination.

8.3 Harmonic distortion and interference

8.3.1 Harmonic distortion

Since they are non-linear loads, all lift controllers and their associated motor drives draw non-sinusoidal currents. These include harmonic currents which will generate harmonic voltages on the power distribution system. The magnitude of the harmonic voltages will be dependent on the impedances of the distribution system and of the power source.

These harmonic voltages can cause damage to other equipment if they exceed the limits specified by the power supply authority or the power system designer. Lift installations which incorporate solid-state controllers (see sections 7.3.3 and 7.3.4) will draw significant harmonic currents. The harmonic currents drawn must not exceed those permitted by the electricity supply authority and these limits relate to the maximum kVA rating of the device drawing the harmonic current. The Electricity Association's *Engineering Recommendation G5/3*[3] sets down limits for the magnitude of the individual current harmonics and the voltage distortion.

Where multiple controllers are provided to control multiple lifts, and they are fed from the same supply, an assessment should be made of how the individual harmonic currents for each individual load will add up. However, in determining the total it should be noted that the arithmetic sum of the individual harmonic load currents is modified by a 'coincidence factor'.

In many large installations, filtering equipment will be needed for the lift controllers to ensure that the harmonic currents drawn do not exceed the supply authority's specified limits. However, filters should not be introduced without considering their adverse effects. For example, under certain load conditions they may cause damage to or malfunctioning of other equipment connected to the power distribution system, particularly power factor correction capacitors.

Information on the magnitude of the harmonic currents drawn by the lift controllers must be conveyed to the manufacturers of any standby power plant. Failure to do so could cause damage to and/or malfunctioning of the standby power system.

8.3.2 Interference

The lift installation will be subject, to varying degrees, to interference caused by voltage disturbances on the mains power supply (i.e. switching surges), induced voltages in control cabling and radio-frequency interference. It is a requirement of *BS 5655: Part 1*[1] that the lift installation will not malfunction as a result of such interference, no matter how caused.

The system designer has a duty to minimise the possibility of interference being caused to the lift installation while the lift manufacturer is responsible for ensuring that the equipment is properly designed and protected to prevent malfunctioning should any interference occur.

It is a requirement of both the IEE's *Regulations for Electrical Installations*[4] and a European Directive[5] that the lift installation will not cause interference to other equipment and/or installations. Both the system designer and the lift manufacturer must comply with these requirements.

The lift installation should be tested to ensure compliance with the various standards concerning interference. In addition, the lift manufacturer should confirm in writing any limitations on the use of radio equipment in the vicinity of the lift installation. In particular, whether hand-held radio transmitters may be used adjacent to the lift controllers during maintenance work when covers are removed or panel doors are open. Similar assurances are also required for the use of hand-held radio transmitters either inside or on top of the lift car. Consideration must also be given to the effect of fixed radio or microwave transmitters mounted on the roof near to the lift machine room.

Attention is drawn to the requirements under *BS 5750*[6] concerning reliability of software or microelectronics-based control systems. Where such systems include safety inter-locks, these must be direct-acting, fail-safe and positive in operation. The use of software-based safety interlocks is not considered safe practice unless they are duplicated by separate control equipment using separately written software.

8.4 Design and installation considerations

8.4.1 Cable routes and fire risk

Where lifts are essential for emergency evacuation or are used for firefighting (see section 5), the cable routes for both the control wiring and the power supplies should be assessed and additional design precautions may be necessary to ensure that essential cables are protected from fire hazards. Where multiple lifts are used for these essential duties, the cable routes should be physically separate for each lift or subgroup of lifts.

Consideration should also be given as to how the integrity of the fire protection is to be maintained throughout the life of the building.

8.4.2 Cable fixings

The basic requirements for electrical installations are identified in the *Electricity at Work Regulations*[7], *BS 5655: Part 1*[1] and the IEE's *Regulations for Electrical Installations*[4]. However, in addition, the initial specification given to the lift manufacturer should state the type of mechanical protection to be provided for fixed wiring in the lift well, machine room and car.

The options available are:

— rigid wiring clipped to surfaces where other mechanical protection is not essential

— PVC conduit and trunking

— steel conduit and trunking.

Table 8.5 Typical interface schedule

Data transferred	Transfer from	Transfer to	Comments
Power supply (voltage, phases, frequency)	Local isolator (rating)	Lift controller	Interface at isolator (load current)
Lift car lighting (voltage, phases, frequency)	Local isolator at controller (rating)	Lift controller (load current)	Fused before isolator Interface at isolator
Lift car power (voltage, phases, frequency)	Local isolator at controller (rating)	Lift controller (load current)	Fused before isolator Interface at isolator
Earthing and bonding (cross sectional area of cable)	Earth bar in machine room	All metalwork	Interface at earth bar bonded to earth
Standby power in operation (contacts close when generator is supplying load)	Standby generator controls (volt-free contracts)	Lift controller	Interface at lift controller
Emergency bell (sound output level of bell)	Lift controller via terminal in lift well at ground floor (24 V DC supply)	Remote bell in entrance hall (24 V DC, 5 A load)	Interface for wiring at terminal box in lift well

Note: The schedule should be extended to cover all interconnections between the lift installation and other services and/or plant in the building.

8.4.3 Wiring interfaces

The initial specification must identify clearly the interfaces between wiring directly associated with the lift installation and wiring for other services. These are likely to include:

— intercom systems

— telephone handsets in lift cars

— warden alarm systems (in sheltered accommodation)

— remote emergency bells

— connections required for equipotential earthing and bonding

— remote monitoring and signalling to building management systems (see section 10)

— heating and ventilation of the machine room and lift well (see section 9)

— lift well lighting

— lift well socket outlets

— fire alarms and detection equipment

— security systems.

Precise information must be provided wherever such interfaces occur to ensure that the correct signals will be transferred. A schedule of interfaces (see Table 8.5) is recommended so that all the relevant parties can comment on the proposed system and confirm that the required signals are compatible.

8.4.4 Well lighting

For compliance with *BS 5655: Part 6*[8], lift well lighting should be installed at intervals of not more than 7 metres, preferably by means of bulkhead-type luminaires with fluorescent lamps. These should be controlled from the lift machine room by a switch with a warning pilot light and by a switch within the lift well either at the bottom entrance or at pit level. The well lighting switch should be accessible from the entrance to the well.

8.4.5 Safety of maintenance personnel

A rubber safety mat should be placed in front of the lift controller and also behind where rear access is provided. A card or poster giving guidance on treatment following electric shock should be provided in the machine room.

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8 *BS 5655: Lifts and service lifts: Part 6: 1990: Code of practice for selection and installation* (London: British Standards Institution) (1990)

9 Environmental factors

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9 Environmental factors

9.1 Introduction

In designing the lift system for a given building, the designer must consider not only the interface of the lift system with the building and its users, but also the more

cooling of the machine room. *BS 5655: Part 6*[1] provides general guidance on these requirements. However, adjustments may be necessary when the precise operating conditions for the building are established since solar heat gain through windows, or waste heat from other parts of sections 7.4 and 8.2). All such electric motors produce heat which is dissipated directly into the machine room.

BS 5655: Part 6[1] gives limits of 5°C and 40°C for the ambient temperature inside machine rooms for electric traction lifts. Except for single-unit installations, it will probably be necessary to provide some means of heating and/or cooling in the machine room to keep the temperature within these limits.

9.2.3 Hydraulic drive

The majority of equipment presently available utilises an electric motor and screw driven pump, submerged in the oil reservoir tank (see section 6.3.3). The amount of heat generated by this system depends upon factors such as car loading, lift speed, travel distances and frequency of use but, in practice, most hydraulic lifts produce considerable amounts of waste heat. Unlike electric traction lifts, this heat is not dissipated directly into the machine room, but into the oil reservoir itself. This has the effect of reducing the oil viscosity.

The opposite effect can be observed during periods of infrequent use, e.g. overnight. Hydraulic lift machine rooms are often placed in architecturally convenient locations, such as basement areas or stair cores. However, in such locations, the ambient temperature may drop considerably, which has a thickening effect upon the oil.

Clearly, it is necessary to maintain the oil viscosity within acceptable limits. *BS 5655: Part 6*[1] lays down ambient temperature limits of 15°C and 35°C within lift machine rooms to assist in maintaining the hydraulic fluid viscosity within suitable limits for optimum performance of the equipment. To achieve these levels, direct oil heating or cooling may be required in many applications (see sections 9.4 and 9.5). This must be provided by the lift supplier.

The waste heat generated by hydraulic lifts is considerably more than that from a comparable electric traction lift, and the problem of heat disposal is often made greater because the machine room is sited within the building rather than on the roof.

9.3 Ventilation

9.3.1 General

Whether or not ventilation is installed as a means of dissipating machine room heat gains, ventilation should be provided in accordance with the requirements of *BS 5655: Part 6*[1].

9.3.2 Lift well

BS 5655: Part 6[1] requires that the well is suitably ventilated and not used to provide the ventilation of rooms other than those for the service of the lifts. It also requires that provision be made at the top of the well for ventilation openings, having a minimum area of 1% of the horizontal cross section of the well, to the outside either directly or via the machine or pulley room. If ventilation is provided via the machine or pulley room, through-ductwork should be used.

For lifts with speed in excess of 2.5 m/s, *BS 5655: Part 6*[1] requires that the vents should be not less than 0.3 m^2 in free area for each lift well. A common lift well for two or three lifts having speed in excess 2.5 m/s requires a minimum vent area of 0.30 m^2. Where the common well accommodates four, five or six lifts, minimum vent areas of 0.40 m^2, 0.50 m^2 or 0.60 m^2 respectively should be used. The vents should be louvred or otherwise protected to prevent rain, snow or birds from entering the lift well.

Local regulations should also be consulted since these may require larger vent areas under certain circumstances.

9.3.3 Machine room

Under the section dealing with machine room construction, *BS 5655: Part 6*[1] recommends that stale air from other parts of the building should not be exhausted into the machine room and that permanent ventilation to the open air should be provided, the free area of which should be not less than 0.1 m^2 per lift.

9.3.4 Lift car

Under normal operation, the environmental conditions within lift cars present few problems. However, consideration must be given to the effects of breakdowns, especially if people are trapped inside a car. For internal lift wells, a small fan extracting air from the car into the lift well may be sufficient.

Heat gains from light fittings should be considered, especially spotlights which can dissipate substantial amounts of heat. If spotlights are used, an emergency 'off' switch should be provided to reduce the lighting to an emergency level.

For external observation lifts, the effects of solar heat gains must also be considered. These may be sufficient to require the provision of air conditioning during normal operation. In the event of breakdown during the summer, the loss of such air conditioning could be dangerous to the occupants and the provision of maintained electrical supplies or even duplicate plant should be considered.

9.4 Methods of heating

9.4.1 Machine room heating

Heating to lift machine rooms should be available twenty-four hours per day, seven days per week. For this reason, local electric heating is widely used, often in the form of thermostatically controlled tubular heaters. Where cooling is also required, packaged heat pumps may offer a cost-effective solution.

9.4.2 Oil reservoir heating

Light duty hydraulic lifts and those hydraulic lifts with machine rooms that are remote or sited in basement areas, may also require oil heaters to ensure that the oil viscosity is at the correct level after, for example, overnight shut-down. This may be readily achieved by an immersed heating element in the oil reservoir, controlled by a thermostat. Such devices must be provided by the lift supplier.

The provision of a separate oil heater, however, does not affect the need to maintain the ambient temperature limits of 15°C and 35°C within the machine room itself.

9.5 Methods of cooling

9.5.1 Machine room cooling

All machine rooms should be provided with adequate means of dissipating the heat generated by the lift equipment. The upper limit of 40°C for electric traction lifts enables outside air to be used as the cooling medium in many areas where ambient temperatures are not high. Care must be taken, however, with hydraulic lifts as the upper limit of 35°C is close to the maximum ambient temperatures likely to be encountered in the UK. In

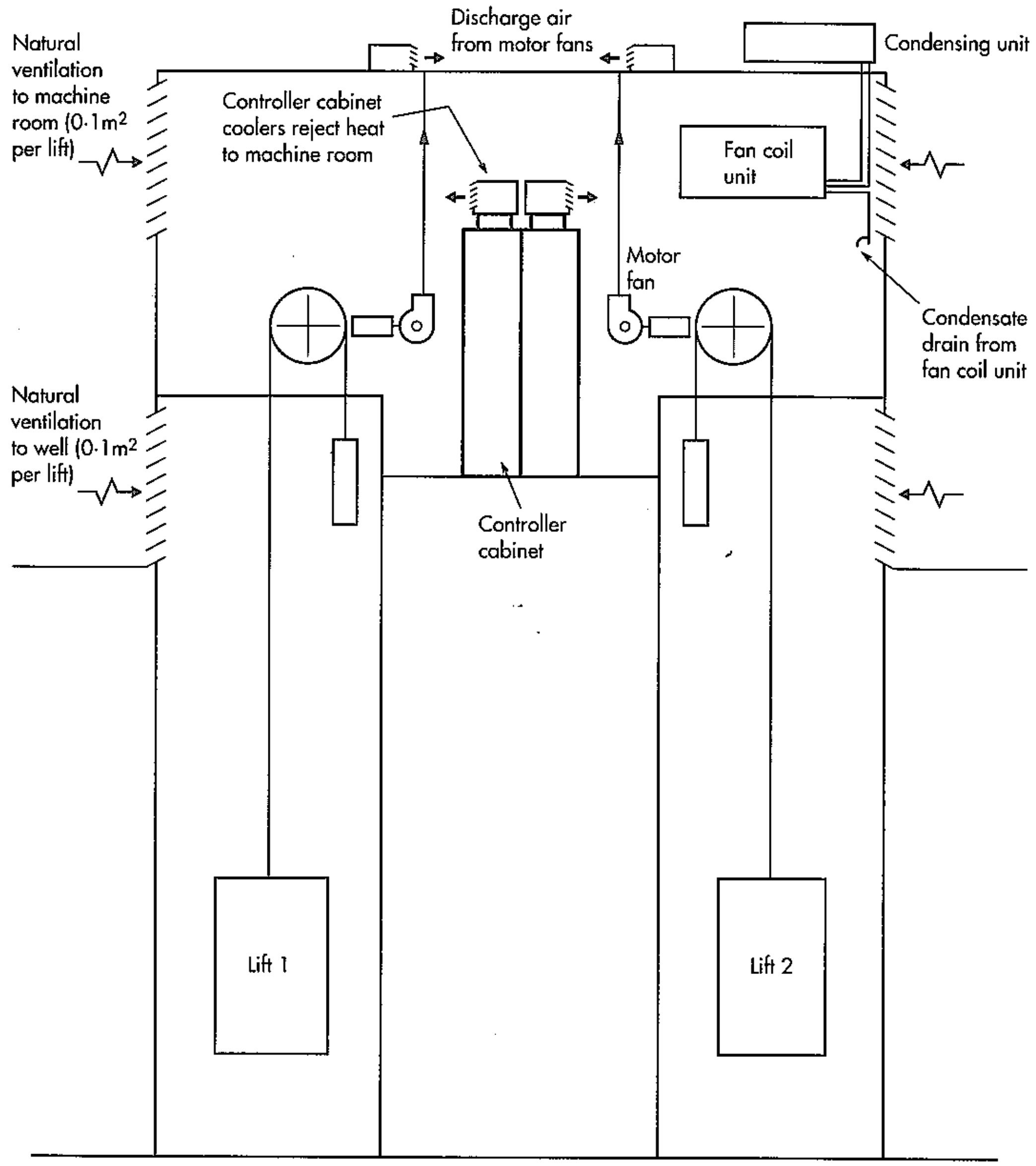

Figure 9.1 Schematic of typical combination heating, ventilation and air conditioning system applied to a rooftop machine room

tropical areas, ambient conditions may preclude the use of ventilation as the sole means of cooling.

The main sources of heat gain within the machine room are the motors themselves, many of which are fan cooled. Rather than allow the hot air generated in the motor to discharge directly into the machine room, it can be ducted to the outside, see Figure 9.1. With some types of motor a secondary fan may be necessary but many motors are fitted with centrifugal blowers which develop sufficient pressure to deal with such discharge by themselves. Where all of the motor air is ducted to the outside, the reduction in room heat gain from the motor can be as much as 75%. This substantially reduces the cooling load and may remove the need to provide machine room air conditioning.

Where cooling air from the motor is ducted directly to the outside, replacement air will have to be drawn in. This can usually be achieved via the permanent louvres provided under the requirements of *BS 5655: Part 6*[1]. However, the replacement air will be warm during the summer and in order to reduce running costs, the set-point of any supplementary cooling system should not be less than the temperature of the incoming air.

9.5.1.1 Natural ventilation

For some single and double lift installations, natural ventilation by convection, using a high- and low-level louvred ventilator arrangement, may be adequate in temperate climates. However, this solution is limited to comparatively low usage lifts.

9.5.1.2 Mechanical ventilation

For high usage lifts, where the heat generated is likely to be significant, and also for groups of lifts, mechanical ventilation will probably be required. This may range from a simple thermostatically controlled fan on the roof which takes in outside air through external louvres up to sophisticated ducted systems. Care should be taken in all cases to prevent local 'hot spots'.

9.5.1.3 Air conditioning

With large multiple lifts and intensive duty hydraulic lifts, vast quantities of ventilation air may be necessary to provide the cooling required. In many instances this is not practicable within the overall building constraints and air conditioning may prove to be a more acceptable means of cooling.

Furthermore, many building operators now consider that the lift machinery will have a longer and more reliable working life if the temperature is maintained well below the upper limit, and therefore require air conditioning to be provided. An additional benefit is improved working conditions for maintenance engineers.

Ideally, air conditioning plant should be located in a separate room so that it can be maintained without entry to the machine room. Where this is not possible and building services engineers are required to work within lift machine rooms, precautions must be taken to ensure compliance with requirements of the *Health and Safety at Work etc. Act 1974*[2].

Machine rooms which rely on air conditioning equipment to control the temperature should be provided with a remote alarm to draw immediate attention to system failures.

Some control panels may require their environment to be more closely controlled than others and require temperatures lower than those specified in *BS 5655: Part 6*[1]. In some cases this may be limited to the control panel itself and panel coolers would be provided. These usually take the form of small proprietary direct expansion air conditioners mounted on top of each panel blowing cooled air downwards through the cabinets, see Figure 9.1.

9.5.2 Oil reservoir cooling

Where the duty of an hydraulic lift is likely to result in the dissipation of considerable amounts of heat into the hydraulic oil, then oil cooling should be considered. This is best provided by the lift supplier as an integral part of the hydraulic pump and power unit. Oil cooling is usually achieved by passing the oil through a radiant fin cooler on its return to the reservoir. It must be remembered, however, that the heat will be dissipated into the lift machine room and this should be taken into account when considering the ventilation and/or cooling of the machine room itself.

9.6 Human comfort considerations

9.6.1 General

The performance of lift installations with respect to noise, vibration and acceleration is subjective and must be considered for each installation individually. The following notes offer general guidance, supplemented by a typical specification, included as Appendix A9.1.

9.6.2 Noise

Criteria for in-car noise levels must take into account lift speed because high-speed lifts are subject to wind noise. In-car noise criteria must also cover noise resulting from door operation. In hydraulic lifts, the oil flow can generate wide-band high frequency noise which is coupled to the lift car via the jack. The addition of a silencer on the valve output can reduce this noise level in the car by up to 8 dBA.

The acceptable level of noise in lobbies will vary according to the function of the building. Noise ratings (NR values) for various areas within buildings are given in *CIBSE Guide A*[3]. NR values are dependent on the frequency spectrum of the noise and there is no constant relationship between NR value and dBA. However, for practical purposes, the NR is approximately equal to (dBA value –6). The recommended NR for reception areas in offices and hotel lobbies is NR40. For areas such as banking halls and open wards in hospitals, NR35 is recommended.

Noise limits in the lift machine room should be specified in accordance with the *Noise at Work Regulations 1989*[4]. It is therefore essential that levels of machine noise are obtained from the lift supplier (see Appendix A9.1).

It is also necessary to ensure that the sound reduction properties of the lift machine room construction, including doors, hatches, ventilation openings etc., are adequate to prevent the escape of noise at levels which exceed the acoustic design criteria for the surrounding areas.

9.6.3 Vibration

Human response to vibration is greatest at low frequencies. Therefore vibration limits in the range 1 to 80 Hz should be specified. Furthermore, human susceptibility to vibration differs between horizontal and vertical vibration and this should be taken into account when specifying acceptable limits of vibration (see Appendix A9.1).

The method of measurement of vibration is important and must be specified precisely. The defined method should be easy to undertake using standard measurement equipment such as 1/3rd octave filters, see *BS 6472*[5]. The use of special filter systems, such as those described in *BS 6841*[6], are not recommended.

9.6.4 Acceleration and deceleration

'Ride quality' is also a function of the acceleration and deceleration and it may be considered necessary to specify criteria for these characteristics.

The typical specification given in Appendix A9.1 represents the upper limit of acceptability. It is not, however, possible to extend this specification to provide a classification which covers the range of lifts required to suit the various applications and types of building. To achieve this, it would be necessary to measure vibration over a wide range of lifts and link the measured levels with subjective standards such as 'adequate', 'good', 'excellent' etc. Classification of ride quality would also need to be related to lift speed and type of drive.

Rates of acceleration and deceleration are obviously linked to optimum lift response times and, to some extent, it may be necessary to compromise between comfort and travel times. To avoid excessive discomfort, it is suggested that lift acceleration and deceleration should not exceed 1.5 m/s^2 and this figure should only be considered where a high degree of control is provided.

9.6.5 Jerk

Passenger comfort will also be affected by the jerk, i.e. the rate of change of acceleration and/or deceleration. Acceptable jerk rates are dependent on the lift speed and the typical specification given in Appendix A9.1 suggests a two-level criterion.

9.7 Environment for maintenance

9.7.1 General

In designing the lift system it is not only necessary to include those provisions required to ensure that the environment is suitable for the satisfactory operation of the lift, but consideration must also be given to those provisions necessary to ensure a safe and suitable environment for those persons involved in maintaining and inspecting the installation. Many of these considerations are identified in the *Health and Safety at Work etc. Act*[2] and/or *BS 7255*[7].

9.7.2 Lift well

BS 5655: Part 6[1] recommends the provision of switched well lighting to ensure a safe working environment for persons working within the lift well. This should preferably be installed by the lift supplier but is often installed by the electrical contractor. Responsibility for subsequent maintenance of the well lighting is unclear because, generally, only the person maintaining the lift is likely to notice the failure of lamps.

A supply of replacement lamps should be kept on site to reduce the delay in replacing failed lamps. In modern buildings, fluorescent lamps are the most common and maintenance will be simplified if lamps of the same type are used for the lift well and machine room.

Well screening is partly covered by *BS 5655: Part 1*[8], and it is recommended that where two or more lifts share a common well, full-height mesh division screens should be provided between each pair of lifts.

Attention should be given to the internal wall surfaces of the well. The walls of the well may be constructed of brick, concrete or block-work, and dry-lined internal facings may also be employed. Each of these can give rise to dust. This should be limited by painting the walls with a suitable proprietary surface treatment. Painting the internal surface of the well will not only inhibit the spread of dust but will also provide a clean and safe working environment. For maximum visibility white paint should be used.

9.7.3 Machine room

The dangers encountered in the machine room are recognised in *BS 5655* and other regulations. The following checklist should be considered when designing or planning machine rooms.

— Guarding of all moving parts: equipment such as overspeed governors should be enclosed in mesh guards. 'Safety yellow' paint may be used to identify moving parts such as traction and deflector sheaves.

— Handrails: any raised machine plinth more than 500 mm above the floor level should have demountable handrails and fixed access ladders or steps.

— Floors: tripping hazards such as trunking or conduit should be eliminated by the use of recessed trunking or trenches. Access trap doors should have demountable handrails or safety chains. Dust-inhibiting paint treatment is recommended.

— Walls: as with lift wells, dust-inhibiting paint treatment is recommended.

— Ceilings: any low-height hazards such as lifting beams should be clearly marked with diagonal hazard-warning stripes.

The following safety equipment should be provided as a minimum:

— notice describing treatment for electric shocks

— hand-held fire extinguishers of a dry type suitable for fires arising from or in connection with electrical apparatus

— rubber isolation floor matting in front of and, where applicable, behind each lift control panel.

References

1 *BS 5655: Lifts and safety lifts: Part 6: 1990: Code of practice for selection and installation* (London: British Standards Institution) (1990)

2 *Health and Safety at Work etc. Act 1974* (London: HMSO) (1974)

3 *Design Data CIBSE Guide A* (London: Chartered Institution of Building Services Engineers) (1986)

4 *Noise at Work Regulations 1989 Statutory Instrument No. 1790* (London: HMSO) (1989)

5 *BS 6472: 1984: Guide to evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz)* (London: British Standards Institution) (1984)

6 *BS 6841: 1987: Guide to measurement and evaluation of human exposure to whole-body mechanical vibration and repeated shock* (London: British Standards Institution) (1987)

7 *BS 7255: 1989: Code of practice for safe working on lifts* (London: British Standards Institution) (1989)

8 *BS 5655: Lifts and service lifts: Part 1: Safety rules for the construction and installation of electric lifts* (London: British Standards Institution) (1989)

Appendix A9.1: Typical specification

A9.1.1 Noise

A9.1.1.1 In-car noise

Door noise, when measured at 1.5 m from the floor and 1 m from the door face with a precision grade sound level meter set to 'fast' response, should not exceed 65 dBA.

Noise levels in the car at the maximum car velocity in the cycle, when measured as above, should not exceed 55 dBA for lift speeds of 0.5–2.0 m/s and should not exceed 60 dBA for lift speeds of 2.0–7.0 m/s.

A9.1.1.2 Lobby noise

Lift noise, when measured at 1.5 m from the floor and 1 m from the door face with a precision grade sound level meter set to 'fast' response, should generally not exceed 55 dBA at any time during the lift cycle. There may be situations, however, where levels up to 65 dBA may be acceptable and this should be checked with the client on each particular project.

A9.1.1.3 Machine room noise

Noise level information shall be made available as follows:

— maximum and average (L50) dBA level over a complete cycle of lift operation

— maximum levels in each of the eight octave bands centred at 63, 125, 250, 500, 1000, 2000, 4000 and 8000 Hz.

The measurements shall be made with a precision grade sound level meter fitted with an octave band filter set. The positions at which measurements are made should be noted on a drawing showing the principal noise-producing elements of the lift machinery. No measurements should be closer than 1 m from any wall or floor surface. All measurements should be made using the 'fast' meter response.

A9.1.2 Vibration

Vibration measurements should be made at the centre of the car, on the floor, in three mutually perpendicular axes corresponding to vertical, front-to-back and side-to-side. Measurements should be made of acceleration level in each direction over two complete cycles, one from the bottom of the building to the top, and one from the top of the building to the bottom.

The measurement method is critical to the repeatability of results. It is, therefore, preferable to use an automatic recorder covering all frequency bands, as opposed to taking individual frequency band measurements over repeated lift runs.

A cycle is defined as the period from just before the doors start to close at one level, to just after the doors open at the final level.

Acceleration levels should be measured as root mean square (RMS) values using a time constant of 0.125 s ('fast'), and the maximum values recorded in each 1/3rd octave band from 1–80 Hz inclusive over each complete cycle. The following limits will apply:

(*a*) Horizontal vibration

— frequency range 1–20 Hz inclusive: maximum (RMS) acceleration level should not exceed 0.1 m/s^2

— frequency range 25–80 Hz inclusive: maximum (RMS) acceleration level should not exceed 0.5 m/s^2.

The above limits apply to any time during a complete cycle, in any 1/3rd octave band in the frequency range specified.

(*b*) Vertical vibration

— at maximum speed: maximum (RMS) acceleration level in any 1/3rd octave band should not exceed 0.08 m/s^2 in the frequency range 1–80 Hz

— during acceleration/deceleration and start/stop periods: the maximum (RMS) acceleration level in any 1/3rd octave band should not exceed 0.15 m/s^2 in the frequency range 1–80 Hz.

The above limits apply to lifts with speeds up to 4 m/s. Lifts having speeds above this will be subject to increased vibration limits. For lift speeds in the range 4–7 m/s, a multiplier of 1.5 may be used for all acceleration level limits.

A9.1.3 Acceleration/deceleration

Acceleration/deceleration of the car should not exceed 1.5 m/s^2 at any time during a complete cycle and should preferably be below 1.2 m/s^2.

A9.1.4 Jerk

The rate of change of acceleration/deceleration (i.e. jerk) of the car should not exceed 2 m/s^3 at any time during the cycle for lifts having a speed above 2 m/s. Jerk for low speed geared lifts should not exceed 3.5 m/s^3.

10 Remote monitoring and interfacing with building energy management systems

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Contents

10 Remote monitoring and interfacing with building energy management systems

10.1 Introduction

In 1990, a study published by the National Economic Development Office on the views of customers on lifts and escalators(1) presented a depressing picture of the vertical transportation industry in Britain and clearly demonstrated the need for all-round improvements in performance.

Microprocessors now provide an inexpensive means of monitoring vertical transportation systems and accumulating data for immediate or later analysis. This section offers some guidelines on remote monitoring and suggests ways in which the resulting data can be used to improve the efficiency of vertical transportation systems, reduce their costs and allow them to be interfaced with other systems within the building.

10.2 General features of basic lift monitoring systems

Figure 10.1 provides an outline of a computerised lift monitoring system (LMS). The general features of such a system should include:

- indication of lift-in-service status
- trapped passenger alarms
- inoperable lift alarms
- performance malfunction (alarms)
- early transmission of alarms and status to the lift maintenance contractor's monitoring control centre
- automatic collection of lift performance data
- two-way voice communication with trapped passengers
- remote configuration of field units
- ability to conduct 'on-line' investigation and analysis of lift activity
- optional measurement of levelling performance
- data analysis.

10.3 Benefits of lift monitoring

There is a danger of collecting so much data that it cannot be assessed and therefore will not be acted upon. A clearly defined management approach is necessary if this is to be avoided. The benefits of monitoring are as follows.

Benefits to passengers:

- increased safety
- increased reliability
- faster response times
- quicker action in the event of breakdown
- quicker action in the event of complaints.

Benefits to the building owner/operator:

- increased safety
- increased availability and reliability
- faster response to callbacks
- elimination of repetitive breakdowns

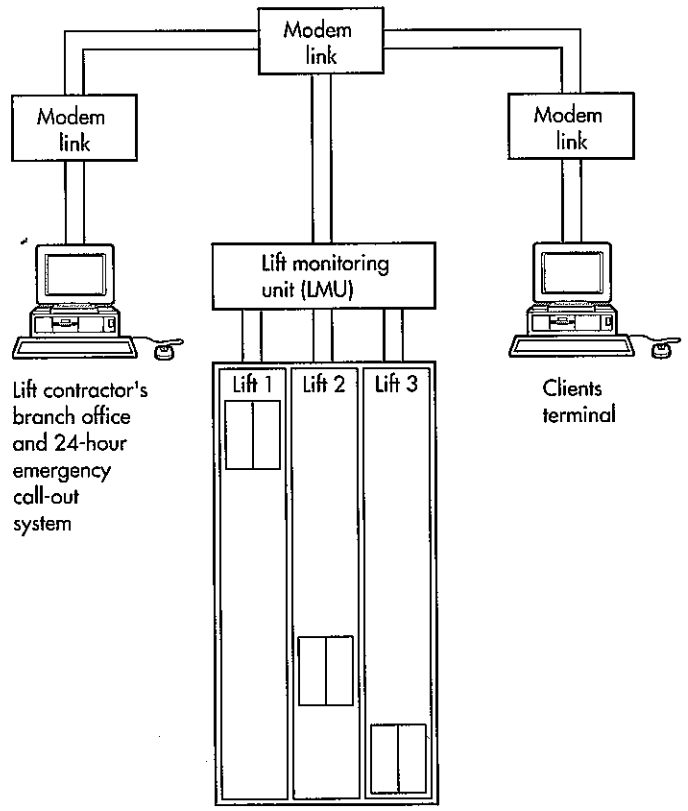

Figure 10.1 Block diagram of basic lift monitoring system

- anticipation of breakdown
- achievement of maximum performance
- establishment of condition maintenance programmes
- 24-hour assistance for trapped passengers
- 24-hour protection against accidental or deliberate damage
- direct contact with lift maintenance contractor's monitoring control centre.

Benefits to the lift contractor:

- provides protection to service base
- provides information to enable field engineers to correct faults more quickly
- faster response to problems
- assists in identifying genuine call-backs where a performance related contract is in operation
- improved fault detection and monitoring of maintenance procedures.

Benefits to design engineers and research and development teams:

- provides feedback from the field to assist with future development
- provides feedback from the field to improve and develop computer-based traffic analysis programs and simulation software.

10.4 Lift monitoring — types of signal

10.4.1 General

Lift controllers handle many different signals. All signals may be classified as one of, or a combination of, three categories of message:

- failure: an event which results in the lift system becoming unserviceable
- error: an event which is not fatal to the operation of the lift system but may result in degradation, malfunction, interruption or failure, and which should be corrected as soon as possible
- status: current information about the operation of the system.

Signals may be logged for one or more of three categories of monitoring:

- basic monitoring: concerned with a lift being in service or not
- service monitoring: enables the status and condition of a lift to be monitored
- performance monitoring: enables traffic analysis to be carried out.

10.4.2 Signals for basic and service monitoring

The following sections list the signals that can be logged for the purposes of basic and service monitoring.

10.4.2.1 Door operation

Door operation signals are as follows:

- door-closing time-out
- 'door hold' pressed for more than 90 s
- door nudging operated
- door overload tripped
- door-opening time-out
- photocell operated for more than 90 s
- door safety-edge operated
- car stopped outside door zone
- 'door close' pushbutton operated
- 'door open' pushbutton operated.

10.4.2.2 Safety functions

Safety function signals are as follows:

- alarm bell activated
- car gate-lock lost while running
- gate-lock power lost
- landing gate-lock lost while running
- locks tipped while at high speed
- locks tipped while at low speed
- lift overtravel, bottom
- lift overspeed
- lift overtravel, top
- primary safety circuit broken
- stop switch activated.

10.4.2.3 Service functions

Service function signals are as follows:

- lift on car-top control
- fire service
- independent service
- maintenance service
- down time exceeds specified number of hours
- down time exceeds specified number of days

- one thousand door operations completed
- one thousand car trips completed.

10.4.2.4 Machine operation

Machine operation signals are as follows:

- failed to start
- motor overload tripped
- machine room temperature high
- relevelling at floor
- journey time exceeded
- machine temperature high
- car load exceeded.

10.4.2.5 Power supplies

Power supply signals are as follows:

- main circuit breaker open
- car pushbutton supply off
- controller power unit off
- landing pushbutton supply off
- logic power unit off
- one phase lost
- phase rotation failure
- supply mains lost
- car lights failed
- shaft lights failed.

10.4.3 Signals for performance monitoring

Signals relevant to performance monitoring are as follows:

- hall up-call registration†
- hall down-call registration†
- car in service
- car position†
- car direction
- lift moving
- car load†
- car door open
- car door closing
- car door closed
- car door opening
- car call registration†.

† More than one signal is required to monitor these functions

10.5 Lift monitoring standards

Some lift companies have developed their own standards and both the British Standards Institution (BSI) and the International Association of Elevator Engineers (IAEE) have offered draft documents.

BSI draft for development *BS DD 176*[(2)] gives basic guidance for remote monitoring but provides only the minimum of recommendations. It suggests numeric identification codes for a variety of fault/event conditions. More recently, European Standard *prEN 627*[(3)] has been circulated for consideration.

The draft international standard *DISD 175: REM 90*[(4)], produced by the IAEE describes three categories of event (status, error and failure) and three categories of monitoring (basic, service and performance). Extensive mnemonic event codes are suggested, together with standard connector arrangements and computer-based interrogation routines.

It is unlikely that a standardised interface for monitoring lift systems will be established in the immediate future. However, a survey[(5)] carried out on draft standard *DISD 175: REM 90* shows that the leading industry suppliers already achieve between 10% and 50% conformance. The remaining 50% is mainly concerned with the *REM 90* definitions of standard connectors and interrogation methods.

10.6 Interfacing with building energy management systems

In current lift monitoring systems, the possibilities for the lift data to reach the end user (e.g. building owner) tend to be limited. The lift and escalator industry can take advantage of the considerable success and widespread application of building energy management systems (BEMS), which are now almost a standard item of equipment within the heating, ventilation, refrigeration and air conditioning industry.

Generally, a building energy management system consists of one or more microprocessor-based outstations which control the operation of the heating, ventilation and air conditioning plant, see Figure 10.2, page 10-4. Outstations are distributed throughout the building in close proximity to the items of plant under control.

The outstations are linked by a data communication network which allows the outstations to intercommunicate and the building operator to supervise the whole system from a central computer known as the supervisor. This connection may be effected by dedicated circuits within the building or over the public switched telephone network (PSTN) via a modem link.

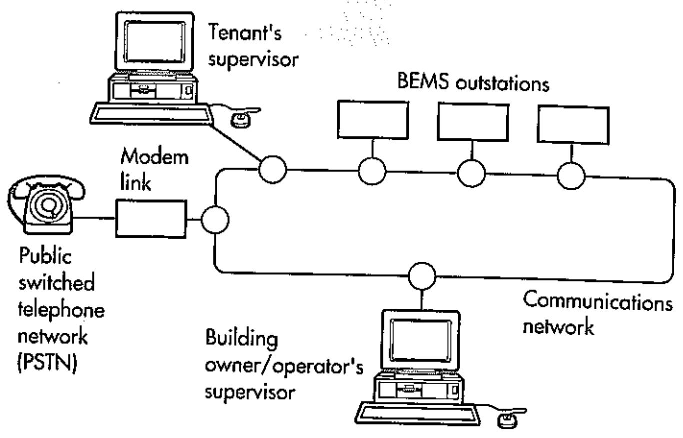

Figure 10.2 BEMS architecture

10.7 Benefits of integration with building energy management systems

When considering the benefits to be gained by connecting any service into a BEMS, the following advantages should be noted:

— Common user interface: the lift system may be accessed using a standard interface which is common to other services within the building, e.g. fire and security.

— Cost savings: a standard interconnection between the lift monitoring system (LMS) and the BEMS should cost less than the additional computer required for local operation of the LMS.

— Space savings: often there is insufficient space for more than one display terminal and keyboard. High-resolution monitors and multiple-task software allows a single display terminal to be used.

— Multiple access point: the BEMS communications network may be used to access the lift control system (LCS) from more than one supervisor computer within the building, e.g. security office, facilities manager's office etc. In such cases the lift system must connect into the BEMS network and not directly to the BEMS control station.

— Use of common software packages: software for BEMS is often integrated with other software such as word-processing, spreadsheets, graphics, databases and statistical packages. These may be used to aid the processing and improve the presentation of lift system data.

10.8 Integration of systems

10.8.1 General

Increasingly, building energy management systems are being used to integrate the operation of systems other than heating, ventilation and air conditioning within buildings, and interfaces are being installed for lift systems, fire, security and lighting control. Information from the various systems is then presented in a coordinated manner via the supervisor. The two main methods of interconnecting the BEMS and the lift system are described in the following sections.

10.8.2 Hardwired interfaces

In the case of hardwired interfaces, digital inputs to the BEMS outstations are directly connected to status outputs from the lift system, see Figure 10.3. This type of interface may be implemented on any lift system which can generate status outputs but is limited to status monitoring. Typically these will be specified as dry contacts by the BEMS manufacturer.

It is sometimes more appropriate to implement a lift management system (LMS) directly using integrated BEMS outstations. Such systems use purpose-designed equipment to gather the data directly from the lift system. This is feasible with outstations which can be configured or programmed but has not been widely adopted because BEMS manufacturers are generally not familiar with lift systems.

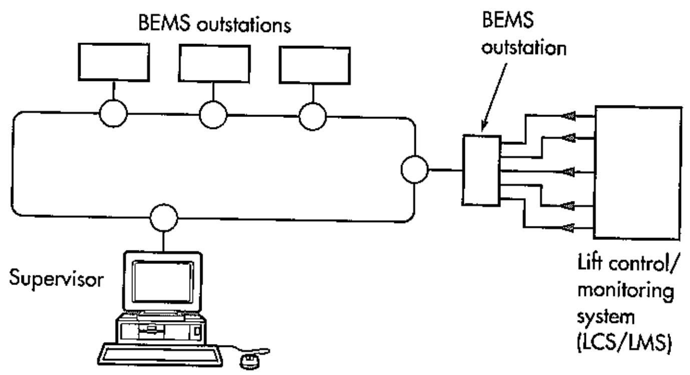

Figure 10.3 Hardwired interface

10.8.3 Data communications interfaces

If the lift system is microprocessor-based there will probably be a communications port by which it can send and receive data. There are usually several points within the BEMS structure to which additional equipment may be connected as follows (see Figure 10.4).

10.8.3.1 Direct into second port of supervisor

The data may be acquired by software supplied by the manufacturer of the lift control system, in which case the interface merely allows the two systems to share the same operator terminal. Alternatively, the data may be acquired by the standard BEMS software, to be processed and displayed in the same way as the BEMS data.

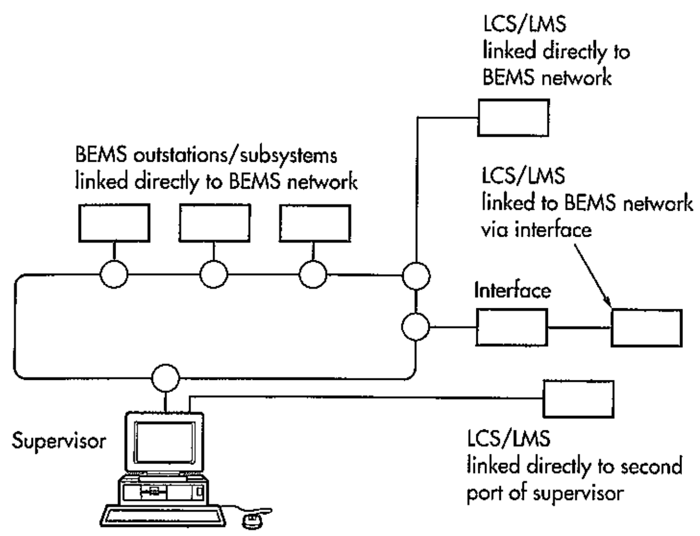

Figure 10.4 Communications interface architecture

10.8.3.2 Network interface onto BEMS network

A network interface will be provided by the BEMS manufacturer which accepts data from the communications port on the lift system and packages the messages for transmission over the BEMS communications network.

10.8.3.3 Direct onto BEMS network

In principle the lift system could be directly connected into the BEMS network. Systems of this type will probably not be encountered until a national or international standard for BEMS networking exists.

10.9 Design and installation requirements for LMS/BEMS interfaces

10.9.1 General

Several different levels of interfacing between LMS and BEMS equipment are possible. It is most important that the requirements of the link are understood before the interface is selected. In general, these requirements are determined by the level of information required at the BEMS supervisor.

Typically, the options available are as follows (in order of complexity). Most of the interfaces available at present or proposed for implementation are at the level of (*a*) and (*b*)

(*a*) Alarm monitoring/event reporting: the BEMS should be able to redirect alarms from the LMS to the maintenance contractor if necessary.

(*b*) Status monitoring: the BEMS should permit car positions and operational status (e.g. door open, closed, jammed) to be viewed.

(c) Recording/analysis: the BEMS should permit fault records and/or a log of engineer calls to be viewed; maintenance statistics to be viewed; performance statistics and/or traffic information to be viewed.

(d) Total control of operation: the BEMS should enable the parameters of the lift control system (LCS) to be changed.

10.9.2 Location of data processing functions

BEMS installers are generally unfamiliar with the operation of lift systems. It is therefore recommended that most data processing functions within the combined system are performed by equipment produced by the LCS manufacturer. These data processing functions include:

— alarm message generation

— generation of maintenance statistics

— generation of performance statistics.

However, building energy management systems are designed to log alarms and other data and to provide further data processing. It is recommended that the collation and presentation of statistics is implemented within the BEMS supervisor.

10.9.3 Location of interface

If an RS232/V24 (or RS423) electrical interface is used the BEMS interface should be positioned as close as possible to the lift control/monitoring system. RS232 links should use screened cable and be restricted to a length not exceeding 2 m. The supposed maximum is 15 m but such lengths are not recommended, particularly where interconnections run close to lift cabling and switchgear. For longer distances an RS485 or RS422 link is more suitable.

10.9.4 Interconnection protocols

The protocol by which two computer systems intercommunicate consists of a comprehensive definition of all aspects of the connection including both the electrical and mechanical features of the connectors. Manufacturers often state that their protocol complies with the 'ISO 7 layer model'[(6)]. In no way does this imply that such a system will communicate with any other system although it may aid the design of communications interfaces between systems. Therefore it is recommended that both manufacturers agree the level of functionality which is to be achieved by their interconnection. This must be based on a written protocol specification.

Alarm messages should be transmitted using acknowledgement and retransmission from the monitoring system in the event of non-delivery. The BEMS data network should be self-monitoring so that any break in the network is brought to the attention of the building operator.

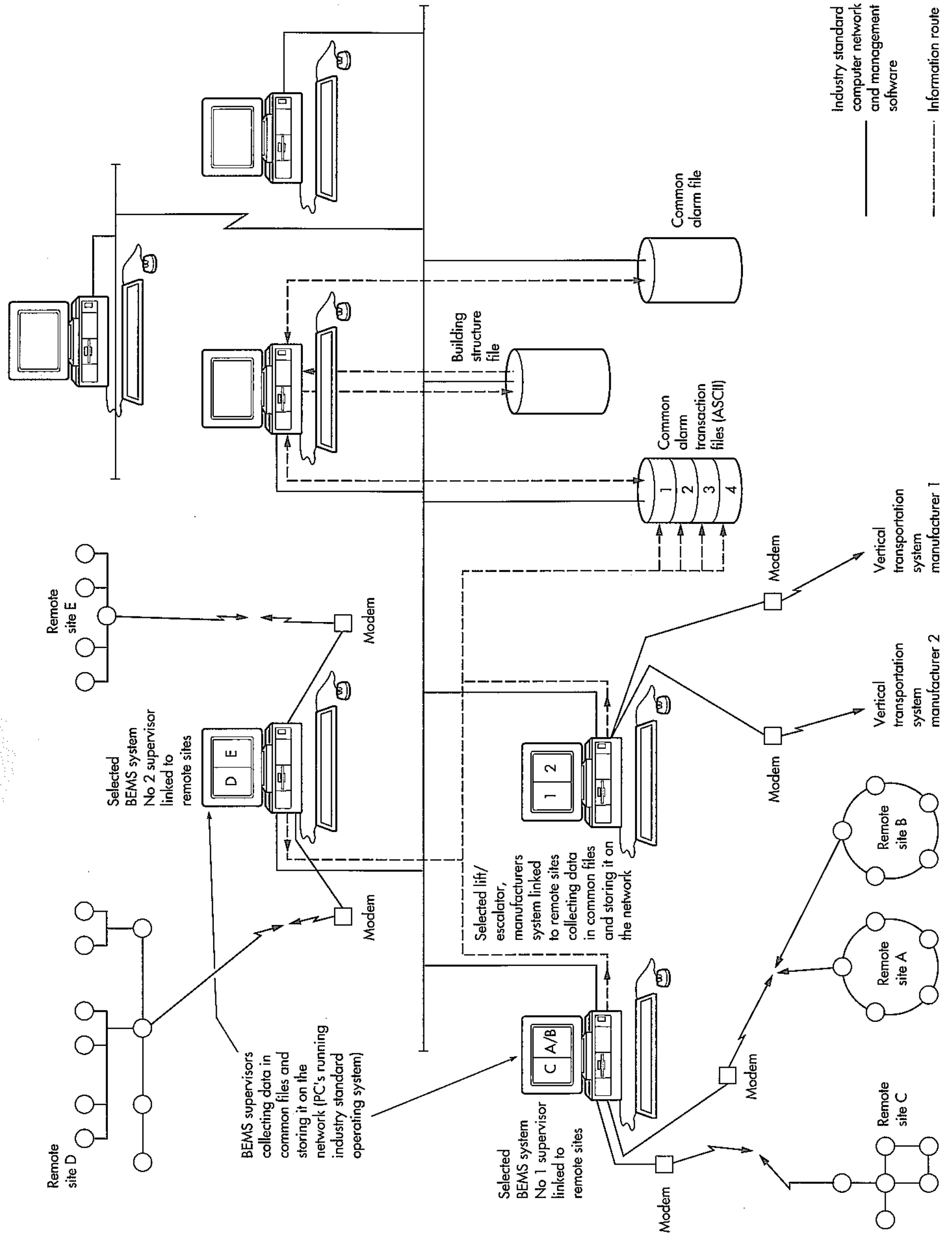

Figure 10.5 Typical building information communications network

10.9.5 Structured cabling and end-user defined networks

Many large companies using building energy management systems have introduced structured cabling and networks as a matter of management policy. To ensure that this policy does not cause them to be committed to a single supplier of BEMS or LCS equipment, industry-standard computer networks and local area network management software can be used. This in turn requires the use of industry-standard personal computers and disk operating systems (see Figure 10.5). Tried and tested proprietary equipment should be used wherever possible to ensure that technical support will be available for both hardware and software.

Large end-users are then in a position to invite selected BEMS and LCS manufacturers to develop (at the manufacturer's cost) interfaces into the end-user's specified network. This is particularly effective for alarms.

10.9.6 Standard communications protocols

Standard communications protocols are being developed for the interconnection of heating, ventilation and air conditioning controllers (e.g. BACnet, Profibus) and for the connection of sensors and actuators (e.g. Echelon LON, EIB, BATIBUS)[7]. Such standards may eventually lead to the full integration of all building services with the internal transportation systems.

References

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2 *BS DD 176: 1988: Data logging and remote monitoring equipment for lifts, escalators and passenger conveyors* (draft for development) (London: British Standards Institution) (1988)

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6 *ISO 7498: 1984: Information processing systems, open systems interconnection — basic reference model* (Geneva: International Standards Organisation) (1984) (available in UK through BSI)

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11 Computer programs and their evaluation

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Contents

11 Computer programs and their evaluation

11.1 Introduction

Modern micro-computers, with suitable traffic analysis software, provide engineers and designers with a powerful tool for determining the number of lifts required, their speed and the size of the cars. Computer programs for lift design, written in Basic, C, Fortran or Pascal, have been available for many years but such programs were time-consuming to develop and generally produce results in the form of numerical data which needed skilful interpretation. The development of spreadsheet techniques and enhanced versions of the above programming languages, has enabled software specialists to produce integrated suites of programs which, in addition to performing the numerical calculations, allow the results to be presented graphically. Many such suites are now available from commercial software producers.

Many of the major lift companies and some lift consultants have available extensive and powerful simulation programs which are particularly useful for undertaking very detailed studies. However, it should be noted that adequate user-training is essential where simulation packages are to be used for traffic analysis and lift design.

Well-designed computer programs use an iterative process to determine the percentage car capacity to meet the requirements of *BS 5655: Part 6*[1] for up-peak handling capacity (i.e. 17% for single tenancy and 12% for multiple tenancy) or any other condition specified by the designer.

The use of computer methods greatly reduces the possibility of errors compared to manual methods. However, with any computer program, it is important that both the data input and the data output are checked by experienced engineers and not simply accepted without question. Manual calculation is strongly recommended in order to check and evaluate the output data.

11.2 Evaluating computer software

It is recommended that answers to the following questions should be obtained as part of any software evaluation exercise:

— for which computer is the program designed?

— which disk operating system is required to run the program?

— which programming language is used and is the source code subsequently compiled?

— who are the authors?

— is the program generally available?

— what are the initial and on-going costs?

— is a detailed manual provided?

— is technical support available and, if so, from whom and at what cost?

— is the program copy-protected and, if so, why?

— is user-training available and, if so, at what cost?

— are there future plans for upgrades, enhancements etc?

It is essential to ensure that the program under evaluation will provide the output data required by the user. It is suggested that a computer program intended for traffic analysis should provide output data for the following parameters:

— time to load and unload passengers at the main terminal (seconds)

— time to load and unload passengers on the upper floors (seconds)

— time to open the lift doors (seconds)

— time to close the lift doors (seconds)

— car start time (seconds)

— expected number of stops

— time to travel the expected number of stops (seconds)

— average highest reversal floor

— average highest reversal floor travel (metres)

— time for express run from average highest reversal floor (seconds)

— round trip time (seconds)

— up-peak interval (seconds)

— nominal travel time (seconds)

— actual up-peak handling capacity (persons per 5 minute period)

— required up-peak handling capacity, single tenancy (unified) (persons per 5 minute period)

— required up-peak handling capacity, multiple tenancy (diversified) (persons per 5 minute period)

- percentage of population actually handled per 5 minute period (%)
- approximate average waiting time for the group (seconds)

11.3 Comparison of programs using a design example

11.3.1 General

In order to compare computer programs, a detailed design example should be formulated to serve as a performance benchmark against which the competing programs may be assessed. The calculations required must first be carried out for the design example using manual techniques to ensure that the benchmark is not biased towards a particular program.

In addition to specifying the input data for the design example, the output data requirements must also be stated, see checklist given in section 11.2.

The objective of the evaluation exercise is to determine which of the programs under investigation provides the best solution to a representative design problem. Therefore, from the results obtained from the program, it should be possible to envisage a design solution which takes account of any special features built into the design example, such as the likely bias between alternative groups of lifts or variations for single and diversified tenancy. Any assumptions made during the performance of the calculation should be clearly stated.

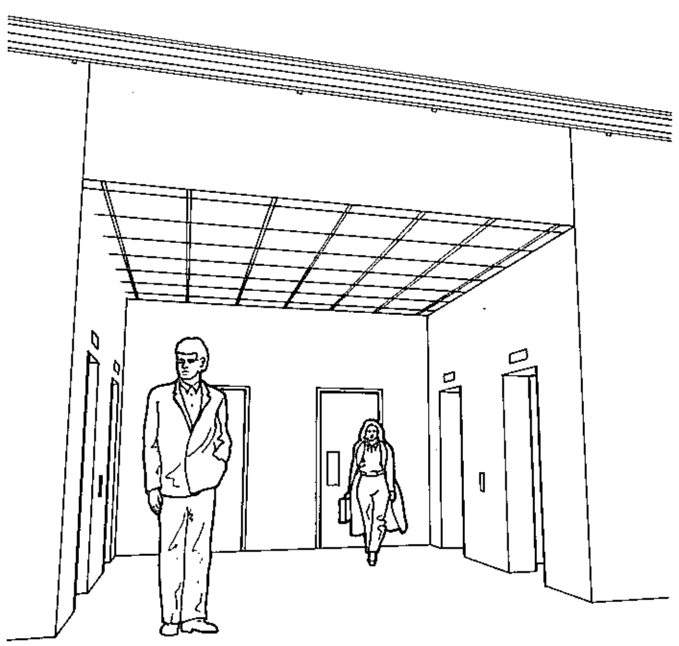

Figure 11.1 Elevation of lift entrances

A specimen design example is given in section 11.3.2. The corresponding manual calculation of the up-peak performance parameters, using the methods described in section 3 (with some modifications), is given in section 11.3.3.

11.3.2 Specimen design example

The specimen building is a major office development for a large prestigious banking/financial institution (company A), having a length-to-breadth ratio of approximately 3:1, see Figures 11.1, 11.2 and 11.3. Part of the development has been assigned as a speculative venture but with the management and security of the building remaining under the control of company A. The development has two main entrances at ground floor level on the long side of the building with access from a main road, well served by public transport.

At each of the main entrances a group of lifts serves all floors including those below ground level but excluding the roof-level plant room. Company A intends to let floors 1 to 3 on long-term leases and floors 4 and 5 on short-term leases.

Motor car access to the car park will be by separate ramps from ground level. Goods and fire lifts will be provided as special groups and will not form part of the passenger transportation system. Goods may be allowed to be carried in the passenger lifts. It may be assumed that the car park will generally be used by directors or senior executives

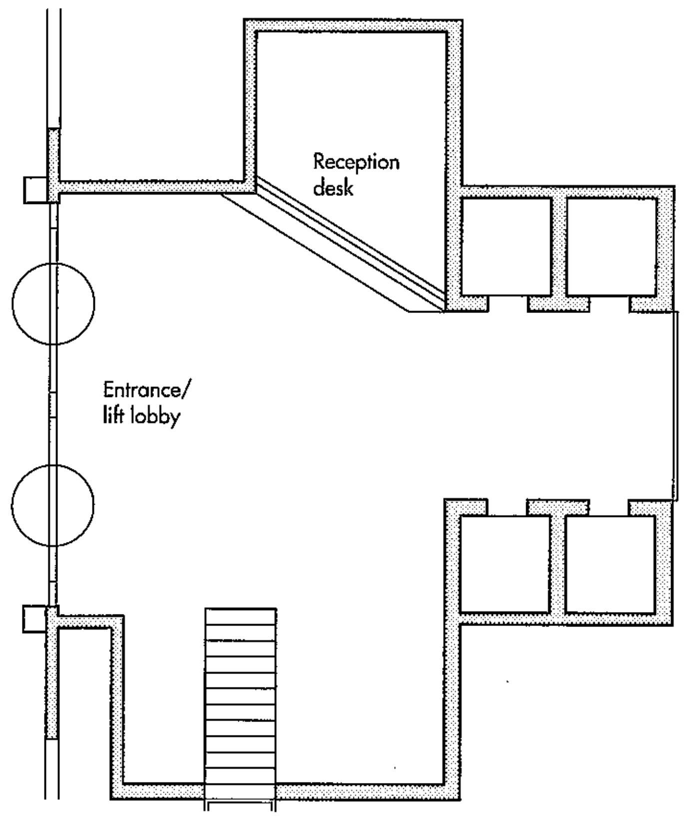

Figure 11.2 Plan of lift lobby

who will demand an efficient service to their respective floors after parking their cars. Access to both groups of lifts is available from the car park.

The schedule of space is set out as in Table 11.1. Values for the basic design parameters are given in Table 11.2.

11.3.3 Up-peak calculation for design example using manual method

11.3.3.1 Transit time between two adjacent floors at contract speed

Using equation 3.4:

$$t_v = d_f / v = 4 / 2.5 = 1.6 \text{ s}$$

11.3.3.2 Time consumed when making a stop

Using equations 3.5 and 3.6:

$$t_s = T - t_v = t_{f(1)} + t_c + t_o - t_v$$

$$= (4.53 + 0.5) + 2.10 + 1.50 - 1.6$$

$$= 7.03 \text{ s}$$

(Note that 0.5 s has been added to $t_{f(1)}$ to account for start-up delays due to door interlocks, motor field time delay, etc.)

11.3.3.3 Floor-to-floor cycle time

Using equation 3.5:

$$t_s = T - t_v$$

Therefore:

$$T = 7.03 + 1.6 = 8.63 \text{ s}$$

11.3.3.4 Round trip time (RTT)

From Table 3.11 using 10-person cars (i.e. P = 8) serving 9 floors, RTT = 94.60 s. As the floor-to-floor cycle time (T) and average interfloor distance (d_f) and average passenger transfer time (t_p) are not the same as the values used in Table 3.11 (i.e. T = 10, d_f = 3.3 and t_p = 1.0). Therefore, the round trip time must be adjusted as follows:

Adjustment for floor-to-floor cycle time, T = 8.63 s:

$$(10.0 - 8.63) \times 6.5 = -8.905$$

Adjustment for average interfloor distance, d_f = 4 m:

$$1.4 \times (4 - 3.3) / 0.33 = +2.97$$

Adjustment for average passenger transfer time, t_p = 1.50 s:

$$3.2 \times (1.5 - 1.0) / 0.2 = +8.00$$

Hence:

$$\text{RTT} = 94.6 - 8.905 + 2.97 + 8.00 = 96.67 \text{ s}$$

The calculated RTT value is considered to be optimistic and some designers may decide that 5% should be added for passenger behaviour etc.

11.3.3.5 UPPINT and UPPHC excluding floors below main terminal

Using equation 3.9, the average up-peak interval assuming four 10-person cars, is:

$$\text{UPPINT} = 96.67 / 4 = 24.17 \text{ s}$$

Using equation 3.11, the average up-peak handling capacity, assuming 80% of maximum capacity, is:

$$\text{UPPHC} = (300 / 96.67) \times 4 \times 8$$

$$= 99.31 \text{ persons/5 min}$$

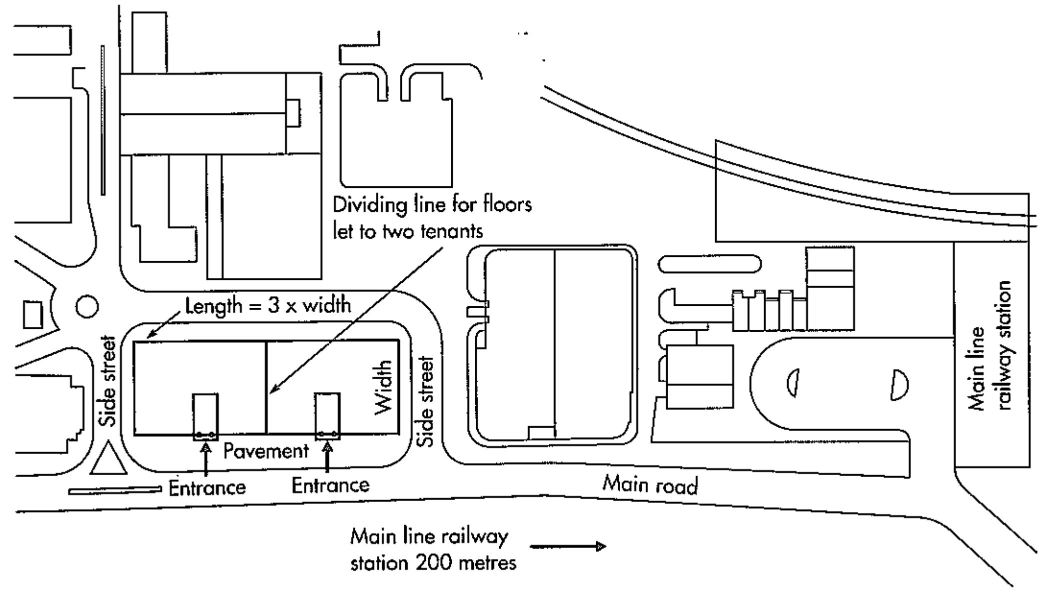

Figure 11.3 Location plan of development

Table 11.1 Design example — schedule of space

Floor	Use of space	Net lettable area (m²)	Floor-to-floor height (m)
Roof	Plant: M&E services	600	4.0
Floor 9	Executive offices (company A)	700	4.0
Floor 8	General offices (company A)	800	4.0
Floor 7	Financial services (company A)	900	4.5
Floor 6	General offices (company A)	1000	4.0
Floor 5	Speculative offices (small units; short lease)	1000	4.0
Floor 4	Speculative offices (small units; short lease)	1000	4.0
Floor 3	Speculative offices (general; long lease)	1000	4.0
Floor 2	Speculative offices (general; long lease)	1000	4.0
Floor 1	Speculative offices (general; long lease)	1500	4.0
Ground	General offices and two large entrance halls (company A)	900	4.0
Basement 1	Car park (general; long and short leases)	(40 spaces)	5.0
Basement 1	Car park (company A)	(30 spaces)	5.0
Basement 1	Technical offices (general; long lease)	500	4.5
Basement 2	Storage (company A)	500	5.0
Basement 2	Restaurant (company A)	(200 seats)	5.0
Basement 2	Storage (general; long and short leases)	500	5.0
Basement 2	Plant: M&E services	1200	5.0

Table 11.2 Design example — values for design parameters

Design parameter	Symbol	Value
Contract capacity	CC	10 persons
Number of floors served above main terminal	N	9 floors
Contract speed	v	2.5 m/s
Average interfloor height	d_f	4 m
Average number of passengers	P	8 persons
Door opening time (800 mm centre-opening doors)	t_o	1.50 s
Door closing time (800 mm centre-opening doors)	t_c	2.10 s
Average passenger transfer time (800 mm centre-opening doors)	t_p	1.5 s
Time delay for various start-up delays		0.5 s
Single floor flight time†	$t_{f(1)}$	4.53 s
Required handling capacity per 5 min:		
— 17% single tenancy (unified)		97 persons
— 12% multiple tenancy (diversified)		68 persons

† see section 11.4.3

Table 11.3 Lift handling requirements per entrance with 65% bias (up-peak only) for the design example

Floor number	Floor area (m²)	Occupancy (m²/person)	Handling requirement at 65% bias
1	1500	10	97
2	1000	10	65
3	1000	10	65
4	1000	10	65
5	1000	10	65
6	1000	10	65
7	900	9	65
8	800	10	52
9	700	15	30
			Total: 569

Based on a handling requirement of 569 persons at 65% entrance bias, see Table 11.3, the percentage handled per 5 minutes is given by equation 3.12:

$$\%\text{POP} = (99.31 / 569) \times 100 = 17.45$$

This is considered an acceptable standard.

11.3.3.6 Average round trip time for floors below the main terminal

The designer must decide how the service below the main terminal will be approached. For this example the following assumptions have been made:

- lift calls alternately at B1 and B2 levels during a round trip.
- average highest reversal floor, $H = 1.5$
- passenger transfer times, $t_{p(in)} = 4.0$ s; $t_{p(out)} = 1.5$ s
- all lifts in the group will serve below the main terminal

- time delay for door safety interlock check and car start, $t_d = 0.5$ s (see section 11.4.3)
- flight time for 5 m interfloor height (see section 11.4.3), $t_{f(1)} = 5$ s
- only one landing call per trip
- no car calls to floors B1 and B2 during up-peak traffic.

Equation 3.3 is modified by substituting $(t_{p(in)} + t_{p(out)})$ for $(2\,P\,t_p)$. Therefore, the following equation may be used to calculate the additional round trip time, RTT′:

$$\text{RTT}' = (2\,H\,t_v) + (S + 1)\,t_s + t_{p(in)} + t_{p(out)}$$

Using equation 3.4:

$$t_v = d_f / v = 5 / 2.5 = 2.0 \text{ s}$$

Using equations 3.5 and 3.6:

$$t_s = t_{f(1)} + t_c + t_o - t_v$$

$$= (5.0 + 0.5) + 2.1 + 1.5 - 2.0 = 7.1 \text{ s}$$

(Again, 0.5 s has been added to $t_{f(1)}$ to account for start-up delays due to door interlocks, motor field time delay, etc.)

Therefore:

$$\text{RTT}' = (2 \times 1.5 \times 2.0) + ((1+1) \times 7.1) + 4.0 + 1.5$$

$$= 25.7 \text{ s}$$

Section 3.11.3 suggests that 15 to 30 seconds should be added to the up-peak RTT, which compares well with this example.

11.3.3.7 Average round trip time above and below the main terminal

The average round trip time above and below the main terminal is calculated by adding the RTT for floors above the main terminal, as calculated in section 11.3.3.4, and the RTT for floors below the MT, as calculated in section 11.3.3.6. Therefore:

$$\text{RTT} = 96.67 + 25.7 = 122.37 \text{ s}$$

11.3.3.8 UPPINT and UPPHC for floors above and below the main terminal

Using equation 3.9:

$$\text{UPPINT} = 122.37 / 4 = 30.59 \text{ s}$$

Using equation 3.11: $\text{UPPHC} = (300 / 122.37) \times 4 \times 8$

$$= 78.45 \text{ persons/5 min}$$

11.3.4 Comments on manual solution to design example

The above example uses the lowest of the car sizes suggested by performing the calculation using various computer programs (see section 11.3.5). In practice, a car size of not less than 13 persons would be recommended for a prestigious office building of this type. In addition, for a car of this size Table 3.4 indicates that up to 9.1 passengers can be accommodated comfortably giving the system the ability to respond to any sudden peaks.

The selection of 4.53 and 5.0 seconds for single floor flight time suggests high quality drive and control systems. High performance door gear would also be necessary in order to achieve the opening and closing times selected. Flight times may also be calculated using speed, acceleration and jerk rate. Section 11.4 provides the relevant kinematic equations.

There can be no single 'correct' solution for the configuration set out in the design example and experience and judgement must be applied in design. Each case must be dealt with individually but it is important to bring together the different time elements to give an overall picture of events.

11.3.5 Results of comparison of computer programs

Nine companies and/or individuals were invited to prepare design solutions for the design example given in section 11.3.2 using their preferred computer programs. The results received for the up-peak calculation are summarised in Table 11.4

Table 11.4 Results of comparison of computer programs for up-peak calculation

Parameter	Range of results
Car capacity	10–16 persons
Speed	1.6–2.5 m/s
Number of cars in each core	4–5
Round trip time	78–105 s
Interval	19.5–26.0 s
Car occupancy	40–80%
Population actually handled in 5 min	17–32%
Entrance bias	50–65%

The range of values for each parameter illustrates the wide variation in the design solutions for the design example, e.g. the choice of car size. To enable a direct comparison between computer programs, it is essential to ensure that all the input data for the design example are specified precisely.

From the results of the design example, it was clear that some of the computer programs were able to deal with up-peak situations only. Such limitations must be carefully considered when evaluating computer software.

11.4 Computer programs for lift dynamics

11.4.1 Simple kinematics

The following basic equations of kinematics should be familiar:

$$s = ut + \tfrac{1}{2}at^2 \qquad (11.1)$$

$$v = u + at \qquad (11.2)$$

$$v^2 = u^2 + 2as \qquad (11.3)$$

For simplicity, these equations assume that the final acceleration value is attained instantaneously. In real systems, such as the movement of a lift car in a shaft, acceleration cannot be attained instantaneously due to factors such as the time delay for drive motor current to reach working values, mechanical stiction, brake release times, etc. In such systems, a body attains its final value of acceleration at a specific rate of change of acceleration, known as jerk.

11.4.2 Lift kinematics

The movement of a lift car from rest at one floor to rest at another floor requires four periods of varying acceleration listed in Table 11.5. These are illustrated in Figure 11.4. It may be seen that:

— maximum velocity is reached when the acceleration is zero

— the distance to be travelled occurs at the end of the four periods

— the process is symmetrical.

The term 'speed' is synonymous with velocity, since scalar rather than vector quantities are implied, and the term 'rated' is used to indicate the designed maximum values a variable can attain.

Table 11.5 Periods of acceleration of a lift car

Period	Jerk	Acceleration
1	Positive constant	Positive increasing
2	Negative constant	Positive decreasing
3	Negative constant	Negative† increasing
4	Positive constant	Negative† decreasing

† i.e. deceleration

In Figure 11.4(a), the rated speed is reached before rated acceleration is attained. This is unlikely for a well designed lift drive system. Figure 11.4(b) is typical of a single floor run for a high speed lift whereby the rated acceleration is reached, but rated speed is not attained. Figure 11.4(c) is typical of a low speed lift or a high speed lift making a multiple floor run and both the rated acceleration and the rated speed are reached.

11.4.3 Equations of motion for lift system

The following equations of motion for a lift system are more complex than those for simple kinematics given above in which the jerk (J) is assumed to be infinite. Motz[2,3] provides details of their derivation, Roschier and Kaakinen[4] contribute summary tables and Schroeder[5] and Barney and Loher[6] suggest computer programs based on the equations (see Appendix A11.1).

The equations are expressed in terms of computer variable names, rather than mathematical symbols, since most of them relate directly to the computer program listing given in Appendix A11.1.

Distance SA (m) travelled in order to reach rated acceleration A (m/s^2):

$$SA = 2\,A^3 / J^2 \qquad (11.4)$$

Time TA (s) elapsed in order to reach rated acceleration A (m/s^2):

$$TA = 4\,A / J \qquad (11.5)$$

Speed VA (m/s) at rated acceleration A (m/s^2):

$$VA = (A * SA / 2)^{1/2} \qquad (11.6)$$

Distance SVM (m) travelled in order to reach rated speed VM (m/s):

$$SVM = (VM^2 / A) + (A * VM / J) \qquad (11.7)$$

Time TVM (s) elapsed in order to reach rated speed VM (m/s):

$$TVM = (SVM / VM) + (VM / A) + (A / J) \qquad (11.8)$$

Note: The times obtained from the above equations are ideal; between 0.2 s and 0.5 s should be added (depending on drive quality) to allow for various start-up delays.

Maximum speed achieved during single floor jump V_1 (m/s):

$$V_1 = \sqrt{(A * d_f) + (A^2/2*J)^2} - (A^2/2*J) \qquad (11.9)$$

If V_1 is less than VM then the flight time $t_{f(1)}$ is then given by:

$$t_{f(1)} = A/J + \sqrt{(A/J)^2 + (4*d_f/A)} \qquad (11.10)$$

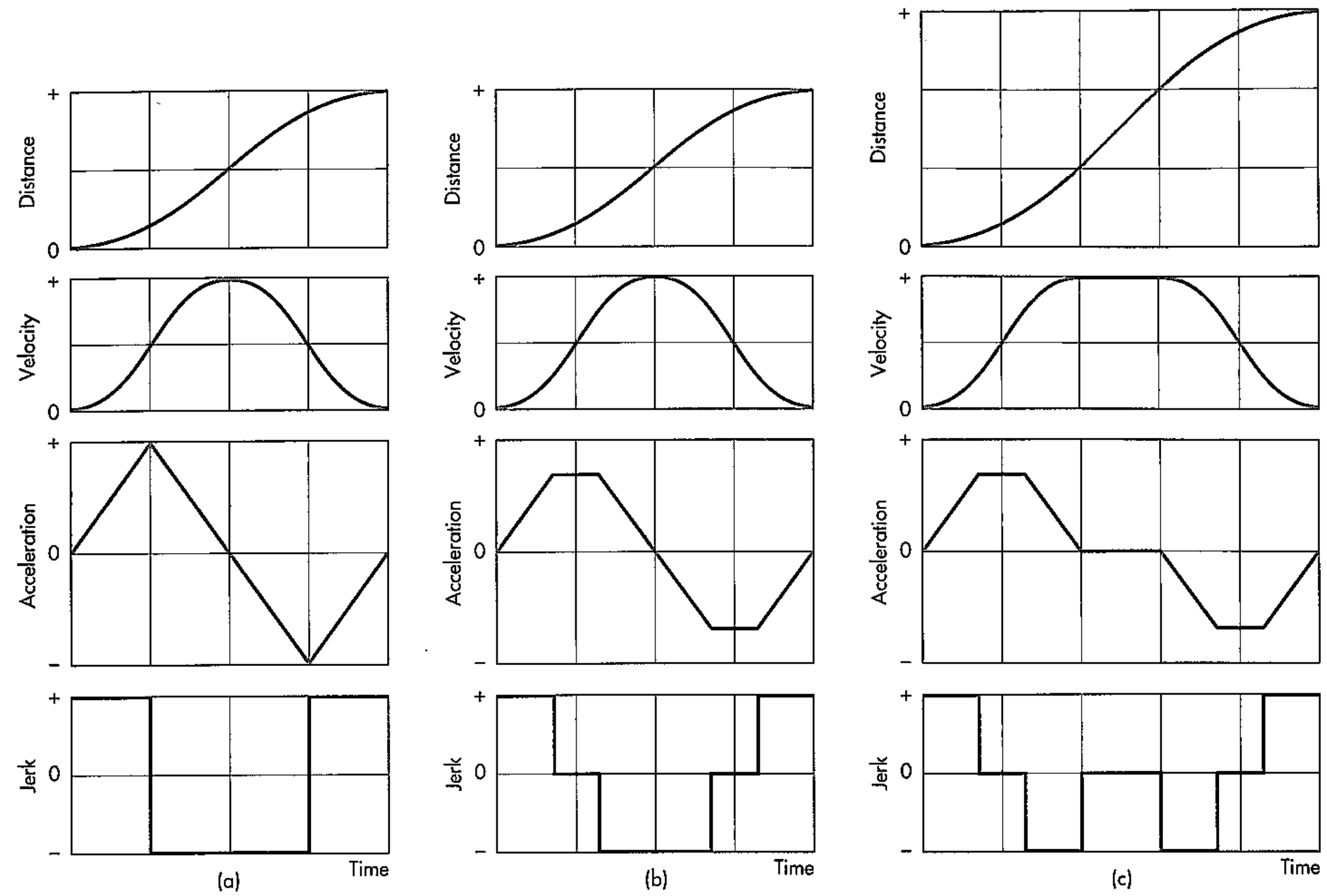

Figure 11.4 (a) rated speed is reached before rated acceleration is attained; (b) rated acceleration is reached but rated speed is not attained; (c) both rated acceleration and rated speed are reached

Example 11.1

Determine flight time (t_f) using following basic data: speed (VM) = 2.5 m/s; acceleration (A) = 1 m/s^2; jerk (J) = 2 m/s^3; floor-to-floor height (d_f) = 4 m.

(*a*) Manual calculation

Distance travelled in order to reach rated acceleration, using equation 11.4:

$$SA = (2 \times 1^3) / 2^2 = 0.5\ \text{m}$$

Time elapsed in order to reach rated acceleration, using equation 11.5:

$$TA = (4 \times 1) / 2 = 2.0\ \text{s}$$

Speed at rated acceleration, using equation 11.6:

$$VA = \sqrt{(1 \times 0.5)/2} = 0.5\ \text{m/s}$$

Distance travelled in order to reach rated speed, using equation 11.7:

$$SVM = 2.5^2 + (1 \times 2.5) / 2 = 7.5\ \text{m}$$

Time elapsed in order to reach rated speed, using equation 11.8:

$$TVM = 7.5 / 2.5 + 2.5 + 0.5 = 6.0\ \text{s}$$

Check maximum speed during single floor jump using equation 11.9:

$$V_1 = \sqrt{(1 \times 4) + (1^2/(2 \times 2))^2} - (1^2/(2 \times 2))$$

$$= \sqrt{(4 + 0.0625)} - 0.25$$

$$= 1.766\ \text{m/s}$$

Check flight time $t_{f(1)}$, using equation 11.10:

$$t_{f(1)} = 1/2 + \sqrt{(1/2)^2 + (4 \times 4/1)}$$

$$= 4.53\ \text{s}$$

(*b*) Computer calculation

Using computer program DYN2S.BAS (version 2), see Appendix A11.1, results were obtained as shown in Tables 11.5 and 11.6. These results are consistent with those obtained by manual calculation, see (*a*) above.

Table 11.5 Floors above ground, $d_f = 4$ m

Floor number	Distance (m)	Flight time (s)	Speed (m/s)
1	4.00	4.53	1.77
2	8.00	6.20	2.50
3	12.00	7.80	2.50
4	16.00	9.40	2.50
5	20.00	11.00	2.50
6	24.00	12.60	2.50
7	28.00	14.20	2.50
8	32.00	15.80	2.50
9	36.00	17.40	2.50
To reach rated acceleration:			
	0.50	2.00	0.50
To reach contract speed:			
	7.50	6.00	2.50

Table 11.6 Basement floor, $d_f = 5$ m

Floor number	Distance (m)	Flight time (s)	Speed (m/s)
B1	5.00	5.00	2.00
To reach rated acceleration:			
	0.50	2.00	0.50
To reach contract speed:			
	7.50	6.00	2.50

References

1 *BS 5655: Lifts and service lifts: Part 6: Code of practice for selection and installation* (London: British Standards Institution) (1990)

2 Motz H D On the kinematics of the ideal motion of lifts *Foerden und haben* **26** (1) 38–42 (1976) (in German)

3 Motz H D On ideal kinematics of lifts *Elevatori* **1/91** 41–46 (1991) (in English and Italian)

4 Roschier N R and Kaakinen M J New formulae for elevator round trip time calculation *Elevator World* (supplement) **28** (8) (August 1980)

5 Schroeder J Elevator trip profiles *Elevator World* **35** (10) 10–11 (November 1987)

6 Barney G C and Loher A G *Elevator Electric Drives* (Chichester: Ellis Horwood) (1990)

Appendix A11.1: Listing of computer program

The following listing is for computer program DYN2S.BAS (version 2) and is based on the equations of motion for a lift system given in section 11.4.3.

```
100 REM *******************************************
110 REM Copyright 1989, 1991, G.C.Barney
120 REM This program calculates flight times for lift systems
130 REM for different values of jerk, acceleration and
140 REM interfloor distance. Three calculations are required:
150 REM (1) Up to constant acceleration AM
160 REM (2) Up to constant velocity VM
170 REM (3) At constant velocity
180 REM Two conditions are possible:
190 REM (A) AM attained before VM
200 REM (B) VM attained before AM
210 REM Supplemetary to this is:
220 REM (a) Are VM and AM reached before floor 1
230 REM (b) Are VM and AM reached after floor 1
233 REM
235 REM Version 2: corrections line 570, simpler formulae lines
237 REM 550 to 580, improved output and comments
240 REM *******************************************
250 REM
260 REM ++++++++++++++++++++++++
270 REM Input and print format
280 REM ++++++++++++++++++++++++
290 REM
300 PRINT "Calculation of lift dynamics (distance, flight
303 PRINT time, speed)"
305 PRINT "Version 2."
310 PRINT
320 INPUT "Acceleration (m/s2)      = ";A
340 INPUT "Jerk (m/s3)              = ";J
360 INPUT "Max rated speed (m/s)    = ";VM
380 INPUT "Floor height (m)         = ";D
400 INPUT "Number of floors         = ";N
420 PRINT TAB(0);"Floor:";TAB(15);"Distance:";TAB
425 PRINT (30);"Flight time:";TAB(45);"Speed:"
430 PRINT TAB(2)"No.";TAB(18);"(m)";TAB(33);"(s)";
435 PRINT TAB(45);"(m/s)"
440 REM
450 REM ++++++++++++++++++++++++
460 REM Calculation of:
470 REM SA distance to reach AM
480 REM VA velocity at AM
490 REM TA time to reach AM
500 REM SVM distance to reach VM at AM
510 REM TVM time to reach SVM
520 REM ++++++++++++++++++++++++
530 REM
540 SA=2*A^3/J^2
550 VA=SQR(A*SA/2)
560 TA=4*A/J
570 SVM=(VM^2/A)+(A*VM/J)
580 TVM=SVM/VM+VM/A+A/J
590 REM
600 REM ++++++++++++++++++++++++
610 REM If VM is not reached by the
620 REM time AM reached goto BLOCK 2
630 REM ++++++++++++++++++++++++
640 REM
650 IF VA>=VM GOTO 1160
660 REM
670 REM ++++++++++++++++++++++++
680 REM BLOCK 1
690 REM ++++++++++++++++++++++++
700 REM
710 I=1
720 S=I*D
730 IF S>SA GOTO 910
740 REM
750 REM ++++++++++++++++++++++++
760 REM Up to AM
770 REM ++++++++++++++++++++++++
780 REM
790 F=((J^2)*S/2)^(1/3)
800 T=((32*S)/J)^(1/3)
810 V=SQR((F*S)/2)
820 GOSUB 1490
830 I=I+1
840 IF I>N GOTO 1630
850 GOTO 720
860 REM
870 REM ++++++++++++++++++++++++
880 REM From AM
890 REM ++++++++++++++++++++++++
900 REM
910 V=-(A^2/(2*J))+SQR((A^2/(2*J))^2+S*A)
920 T=A/J+SQR((A/J)^2+4*S/A)
930 IF V>VM GOTO 1040
940 GOSUB 1490
950 I=I+1
960 IF I>N GOTO 1630
970 S=I*D
980 GOTO 910
990 REM
1000 REM ++++++++++++++++++++++++
1010 REM At VM
1020 REM ++++++++++++++++++++++++
1030 REM
1040 T=TVM+(S-SVM)/VM
1050 V=VM
1060 GOSUB 1490
1070 I=I+1
1080 IF N<I GOTO 1630
1090 S=I*D: GOTO 1040
1100 REM
1110 REM ++++++++++++++++++++++++
1120 REM BLOCK 2
1130 REM ++++++++++++++++++++++++
1140 REM
1150 REM Calculate SVM and TVM.
1155 REM
1160 SVM=SQR((4/J)*(VM^3))
1170 TVM=((32*SVM)/J)^(1/3)
1180 I=1
1190 S=I*D
1200 IF S>SVM GOTO 1370
1210 REM
1220 REM ++++++++++++++++++++++++
1230 REM Up to SVM
1240 REM ++++++++++++++++++++++++
1250 REM
1260 F=((J^2)*S/2)^(1/3)
1270 T=((32*S)/J)^(1/3)
```

```
1280 V=SQR((F*S)/2)
1290 GOSUB 1490
1300 I=I+1: GOTO 1190
1310 IF N<I GOTO 1630
1320 REM
1330 REM +++++++++++++++++++++++
1340 REM From SVM
1350 REM +++++++++++++++++++++++
1360 REM
1370 T=TVM+(S-SVM)/VM
1380 V=VM
1390 GOSUB 1490
1400 I=I+1
1410 IF N<I GOTO 1630
1420 S=I*D
1430 GOTO 1370
1440 REM
1450 REM +++++++++++++++++++++++
1460 REM Printing results
1470 REM +++++++++++++++++++++++
1480 REM
1490 PRINT TAB(1);
1500 PRINT USING "##";I;
1510 PRINT TAB(16);
1520 PRINT USING "###.##";S;
1530 PRINT TAB(30);
1540 PRINT USING "###.##";T;
1550 PRINT TAB(43);
1560 PRINT USING "###.##";V
1570 RETURN
1580 REM
1590 REM +++++++++++++++++++++++
1600 REM Printing SO and SV results
1610 REM +++++++++++++++++++++++
1620 REM
1630 PRINT "To reach rated acceleration:"
1635 PRINT TAB(16);
1640 PRINT USING "###.##";SA;
1645 PRINT TAB(30);
1650 PRINT USING "###.##";TA;
1655 PRINT TAB(43);
1660 PRINT USING "###.##";VA
1670 PRINT "To reach contract speed:"
1675 PRINT TAB(16);
1680 PRINT USING "###.##";SVM;
1685 PRINT TAB(30);
1690 PRINT USING "###.##";TVM;
1695 PRINT TAB(43);
1700 PRINT USING "###.##";VM
1710 PRINT ""
1715 PRINT: PRINT
1720 END
```


12 Commissioning, inspection and maintenance

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Contents

12 Commissioning, inspection and maintenance

12.1 Introduction

This section outlines the concepts behind the commissioning of new lifts and escalators and details the subsequent maintenance requirements during their operational life. It identifies the various regulatory and inspection bodies and explains their roles in the safe operation of lift and escalator systems. Guidance is also given on the refurbishment of lifts.

12.2 Commissioning

12.2.1 General

Commissioning covers those activities undertaken to ensure compliance with specified requirements. Within the framework of the *Health and Safety at Work etc. Act 1974*[1], a supplier has a responsibility to ensure that supplied goods are suitable for the stated intended purpose. This is in addition to the contractual responsibility to ensure that the goods are in accordance with the contract specification. Therefore lift manufacturers normally undertake their own systems of checks at various stages within the contract. The relevant design code or standard for the unit (e.g., *BS 5655*, *BS 5656* etc.) may also recommend certain site tests to be undertaken on completion of installation work.

The client may supplement these systems with inspections by their own personnel or by a third party. Such third parties may be insurance companies or inspection organisations or consultancies which specialise in lifts and/or escalator systems. The intention to carry out such inspections should be specified in the early stages of contract negotiation so that adequate provisions can be incorporated.

A prerequisite to commissioning is possession of the relevant contract documents including dimensioned drawings and specifications, together with details of all agreed changes effected since origination. In practice, even final installation drawings are commonly amended on site by agreement between those present at the time.

Specifications provide the contractual means by which specific requirements are recorded by the parties involved. In their most basic form, they may be based on a manufacturer's catalogue or a British Standard. Specifications are also used to define particular requirements such as the desired performance or the handling characteristics. In some cases it may be necessary to define the environmental standards required, see section 9.

Specifications should also identify particular documentation requirements. For example, European Standard *EN 81: Part 1*[2] and *Part 2*[3] set out the particular documentation required within a technical specification. This requirement is omitted from *BS 5655: Part 1*[4] and *Part 2*[5] under a national variation for the UK but there is a case for requiring that all the information identified in *EN 81* be provided, particularly in view of the future harmonisation of legislation and/or standards within Europe and changes in professional liability legislation.

The documentation prepared by the supplier should be checked to ensure compliance with the purchaser's requirements as an integral stage of commissioning. Any omissions or errors must be notified accordingly. Often this stage reveals oversights of detail known only to the client, or the innocent inclusion of minor variations by the supplier in order to match a standard product item.

The preliminaries having been duly agreed, 'supply' of the lift or escalator unit commences. The programme of checks undertaken on the unit may be broadly grouped as follows:

— off-site, during manufacture

— on-site, during installation

— on-site, on completion.

12.2.2 Off-site checks during manufacture

For all supply organisations, manufacture of a lift or escalator involves a combination of buying in manufactured components and producing components from raw materials. Reputable manufacturers will have systems of tests and controls, within the production cycle, to ensure compliance with specified requirements. These may relate to the purchase of materials, components or subassemblies, machining or fabricating processes, packaging, storage, transportation, installation etc. The systems are tailored to the organisation's general production requirements but may be supplemented by special conditions to meet the purchaser's requirements.

For standard lift units, the benefits of imposing additional or special tests during this stage of supply rarely justify the expenditure involved. Such tests are normally recommended only where the unit is beyond the manufacturer's normal capacity, e.g. some special configuration, or where significant development risks are involved.

Many manufacturers are introducing quality management systems, see section 12.5. Where these are in place, it is common to find 'manufacturing quality plans' which cover materials, drawings, processes, equipment etc., and the manufacturing interfaces during production. Such systems, if developed within a quality conscious manufacturing environment, afford increased assurance to the purchaser.

12.2.3 On-site checks during installation

After factory testing, escalator units and pre-assembled lift components will be transported, perhaps over long distances, transferred across a building site or through a building and hauled into position, all of which may result in the need for adjustment or realignment. Pre-assembled components will then be connected to other components, structures and, usually, a power supply to produce the final installation. To reassure both the client and the manufacturer, the unit should be tested on completion of installation. For escalators specified to *BS 5656*[6], as is usual in the UK, this standard includes a requirement to test the installation and issue appropriate certification.

Unlike most escalators, lifts are generally supplied to the site as consignments of components for assembly/re-assembly in the lift well. For lifts specified to *BS 5655* or similar, there is a requirement under *BS 5655: Part 10*[7] for commissioning tests to be performed and appropriate certification to be issued. Prior to commencement of installation, the manufacturer should carry out checks on the lift well within which the equipment is to be installed to verify its general alignment, finish, dimensions, location of fixings etc. Additionally, manufacturers normally undertake intermediate tests and checks at various stages during installation.

Alignment tolerances for lifts are becoming increasingly critical due to the increased emphasis on quality of ride, the tendency towards higher running speeds, and the development of steel framed buildings and 'fast-track' building techniques. This is particularly true for car and counterweight guide rails and the relative positions of the machine. Manufacturers have developed schedules for checking these items since errors left undetected until completion are expensive and time consuming to correct. Similarly, alignment and fixing of landing door equipment, door locks, fixings for lift well switches and other internal equipment will be checked at appropriate stages during installation when the respective items are easily accessible.

It is normal practice to document these checks, together with the relevant documentation (i.e. drawings, specification, procedures, etc.), references and progress authorisation levels, on what may be termed an 'installation quality plan'. This plan may also include other relevant information such as the names of personnel identified as site contacts (e.g. site agent, third party inspector etc.) or details of materials supplied (e.g. identification, quantities and locations). The installation quality plan provides a means by which interested parties can monitor the installation process and identify specific areas of concern where supplementary checks or inspections may be required.

The majority of escalators are supplied to site pre-assembled. Accordingly, checks on standard units during the installation process are generally confined to structural alignment and positional accuracy of fixings. Usually it is only special units that require extensive site assembly, such as the unusually long units required on the London Underground system. In such cases, an installation quality plan may be required.

12.2.4 On-site checks after completion

The recommended forms for reporting lift tests are given in *BS 5655: Part 10*[7]. There is no 'standard' report form for escalators but an example test certificate issued by a UK escalator manufacturer is shown in Appendix A12.1, Figure A12.1.

Following testing of the apparatus, the applicable codes and/or standards recommend inspection as an integral part of the test procedure. This inspection involves examining the completed installation for conformity with the specification and with regard to proper workmanship. Although usually carried out by the manufacturer, third party inspection is often specified at this crucial stage of the client acceptance process.

This inspection generally results in two reports, the first of which, commonly known as a 'snagging list' identifies items requiring attention by either the manufacturer or other parties involved in final installation (e.g. electrical supply contractor, builder, etc.). These items may be minor and rectifiable immediately or of a more serious nature involving protracted contractual negotiations.

The second report is the outcome of a thorough examination. *BS 5655*[2,3] recommends that, in addition to the commissioning tests, lifts should be thoroughly examined, and a suitable report issued, before being put into service. This recommendation is reiterated in the Health and Safety Executive's *Guidance Note PM7*[8].

For lifts installed in premises covered by either the *Factories Act 1961*[9] or the *Offices, Shops and Railway Premises Act 1963*[10], it is a statutory requirement that an examination be made by a competent person, see section 12.3.6, at least once within every period of six months and a report containing prescribed particulars issued on a prescribed form (Form F54), see Appendix A12.1, Figure A12.2. For lifts in premises not covered by these Acts the relevant British Standards and Health and Safety Executive *Guidance Notes* recommend that such a report be obtained.

For escalators there are at present no specific statutory provisions which require that a report of examination be provided. However *BS 5656*[6] recommends that such a report be obtained and a suitable format is suggested in HSE *Guidance Note PM45*[11].

The codes or standards pertaining to the unit generally specify the tests to be undertaken on completion of the installation, as follows.

12.2.4.1 Electric traction passenger and goods lifts

The tests required by Appendix D2 of *BS 5655: Part 1*[4]:

- landing door locking devices
- electrical safety devices/systems
- suspension elements
- braking system
- measurement of speed and current (or power)
- insulation resistance and earth continuity
- limit switches
- traction and balance
- overspeed governor
- car safety gear
- counterweight safety gear (if fitted)
- buffers
- alarm devices
- functional tests.

12.2.4.2 Hydraulic passenger and goods lifts

Appendix D2 of *BS 5655: Part 2*[5] makes similar requirements to the above but excluding braking system and traction and balance and including the following:

- limitation of piston stroke
- measurement of full load pressure
- relief valve
- rupture valve
- restrictor device
- system pressure test
- creeping and anti-creep devices
- emergency lowering systems
- motor run time limiter
- fluid temperature detecting device.

12.2.4.3 Escalators

Tests required by section 16 of *BS 5656*[6] cover the following items:

- safety devices
- braking system
- insulation resistance and earth continuity
- functional test.

12.3 Requirements for routine inspection

12.3.1 General

The following sections summarise the legislative provisions relating to the inspection of lifts and escalators. There are specific UK statutory regulations which have a direct bearing on lifts. However, at present there is no specific UK legislation related to escalators.

It is within the framework of such legislation and guidance that thorough examinations of equipment should be conducted.

12.3.2 *Health and Safety at Work etc. Act 1974*

The provisions of the *Health and Safety at Work etc. Act 1974*[1] generally apply to lifts and escalators. Specific reference should be made to the following sections:

- Section 3: the duty of employers and self-employed to conduct their undertakings in such a way that people they do not employ are not put at risk.
- Section 4: the duty of owners of premises to maintain safe conditions for persons other than employees who may use or come into contact with equipment within premises.
- Section 6: the duty of suppliers, importers and/or manufacturers to ensure equipment is safe for its intended use (including incorporation of safe means of cleaning, maintenance, setting and inspection) and is supplied with adequate information regarding safe use.

All these provisions must be complied with insofar as is reasonably practicable.

12.3.3 *Factories Act 1961*

Sections 22 to 25 of the *Factories Act 1961*[9] require lifts to be thoroughly examined by a competent person at least once in every period of six months (twelve months for continuous hoists or lifts and those not connected with mechanical power) and a report of the examination to be retained, see Appendix A12.1, Figure A12.3.

Where examination reveals the lift to be in a condition likely to prejudice its safe use, the examiner must forward a copy of the report to the relevant Health and Safety Executive inspector within 28 days.

The Hoists Exemption Order (SI 715)[12] defines certain types of lifts, including manual lifts (i.e. dumb waiter types), continuous (paternoster) lifts and doorless car lifts, which may be conditionally exempted from specified clauses of the *Factories Act* and details alternate provisions.

12.3.4 Offices, Shops and Railway Premises (Hoists and Lifts) Regulations 1967

These *Regulations*[13] make similar requirements to those given in the *Factories Act* and the associated *Hoists Exemption Order*. However, serious defects are notifiable to a local authority (environmental health) inspector and not to a Health and Safety Executive inspector.

12.3.5 Health and Safety Executive

The Health and Safety Executive produces *Guidance Notes* on particular topics in pursuance of its duty to advise industry on safety matters. Four of these[8,11,14,15] are of specific relevance to inspection of lifts and escalators, see below. In addition, *Guidance Note PM8*[16] deals with paternosters which are now virtually obsolete.

12.3.5.1 Lifts: thorough examination and testing: *PM7*

PM7[8] provides guidance to persons responsible for arranging thorough examinations and to competent persons carrying out such examinations. It recommends maximum intervals between examinations of certain key components of lifts. In summary, the following areas are addressed:

— Thorough examination: recommends this be carried out by a competent person at intervals not exceeding six months (except in the case of hand-powered lifts and continuous lifts, such as paternosters, where the period is twelve months).

— Landing and car door interlocks: recommends a maximum interval of twelve months for functional check and that these comply with statutory requirements (i.e. that landing doors cannot be opened except when car is at that landing (mechanical) or that the car cannot be moved from that landing unless the gate is closed (electrical)).

— Worm and other gearing: suggests that the extent of backlash and extraneous noise are generally ascertainable from external examination but that it may be necessary to dismantle the gearcase, particularly if excess wear is indicated. It recommends a maximum interval of ten years for exposure of internal parts.

— Main drive system components: recommends exposure at ten-yearly intervals for shafts, plain bearings and pulleys where parts are not readily accessible. For roller, ball and needle bearings, *PM7* recommends that exposure should be considered only when evidence from other means indicates excessive wear since dismantling such components may in itself prove detrimental to their integrity.

— Governors: recommends that overspeed governor, where fitted, should be functionally checked at five-yearly intervals and after any repair e.g. renewal of governor rope.

— Safety gear: recommends an initial full load/speed test which is to be repeated only after major modification. It suggests that moving parts of safety gear should be inspected at every thorough examination and that operational testing, by engagement of safety gear at slow speed, should be carried out at five-yearly intervals.

— Suspension ropes: identifies the main factors likely to affect rope integrity (i.e. rope terminations, lubrication and environment, wear and age, and broken wires) and provides a guide to certain rope rejection criteria.

— Suspension chains: identifies relevant deterioration factors which should be checked at every examination, and recommends removal at ten-yearly intervals for thorough cleaning, close examination and, where appropriate, relubrication.

— Overload detection devices: recommends that, where fitted, these should be recalibrated at intervals not exceeding twelve months.

12.3.5.2 Safety at lift landings: *PM26*

PM26[14] offers guidance to those responsible for arranging examinations, repair or maintenance of lifts regarding the measures required to ensure continued safety during opening of landing entrances.

This *Guidance Note* reinforces the requirement to establish safe systems of work for these potentially dangerous activities.

12.3.5.3 Safety in the use of escalators: *PM34*

PM34[15] offers guidance on the risks associated with the use of escalators and recommends standards of safety to be met by those in charge of premises in which they are installed. In summary, the areas covered are as follows:

— Manufacturing standards: recommendations are given to comply with the relevant British Standard, now *BS 5656*[6], based on European Standard *EN 115*[17].

— Escalator hazards: identifies typical hazards encountered, generally falling and trapping hazards.

— Precautions against trapping: recommends that persons responsible for the safe use of escalators assess their own equipment with regard to user safety (e.g. type and age of escalator, location, environment and type of people using it).

— Emergency stopping devices: recommends accessible and conspicuous positioning of emergency stop buttons at each landing and at 12 m intervals on long escalators.

— Warning and other signs: recommends subject and nature of warning signs to be posted.

— Precautions against falls: recommends provision of adequate illumination at landings, and also sufficient unrestricted areas to reduce congestion. If there are other suitable means of access to and egress from areas within premises then use of stationary escalators should not be permitted.

— Training, instruction, supervision: recommends training and instruction of personnel in the correct use of escalators and hazards arising from their misuse.

— Maintenance and inspection: highlights aspects to be checked on a day-to-day basis by a responsible person. *PM34* recommends thorough examination by a competent person at intervals not exceeding six months. The report should be kept available for inspection. Mention is made of the report format but this is generally superseded by that recommended in *PM45*[11], see section 12.3.5.4.

12.3.5.4 Escalators: periodic thorough examination: *PM45*

PM45[11] identifies the absence of specific legal requirements for the examination of escalators and provides guidance on what the examination should include and how frequently it should be carried out, and provides an example of a typical reporting format, see Appendix A12.1, Figure A12.1.

In summary, this *Guidance Note* recommends that the following items be incorporated into the thorough examination undertaken at six-monthly intervals by a competent person:

— Running clearances to be monitored.

— General operation to be checked.

— Visual examination of condition of treadway material, balustrade, skirting and handrail and check relative speed of handrails.

— Examination of step roller guides (which may require removal of one or more steps to afford access) and check on step tread/riser meshing.

— Examination of step chains and chain wheels for wear, cracking, extension etc.

— Examination of main drive system and gearing. At ten-yearly intervals, removal of short lengths of the step chain for close examination and exposure of inaccessible parts of the main drive system and gearing for close examination is recommended.

— Operational check of safety devices including power failure, earth fault, overload cutout, chain break/elongation cutout and comb switches, handrail entry guards and switches, step sagging cutouts, non-reversal devices and overspeed governors. Emergency stopping devices should be checked and the braking system efficiently monitored. Balustrade skirting deflector devices should be checked.

— Check of lighting of escalator and surroundings, and the posting of appropriate notices.

12.3.6 Competence of persons carrying out inspections

By whom such inspections are undertaken is the subject of commercial as well as technical consideration. All persons who undertake these examinations should be 'competent' which maybe defined as follows: 'A person with adequate training, both theoretical and practical, and experience of the equipment under examination to enable true assessment of its condition for continued safe operation, supported within an appropriate organisation.'

Training and experience are subjective issues which depend on the complexity of the equipment likely to be encountered. For example, a person whose only training in lift technology was undertaken 15 years ago and who has subsequently had limited direct experience is unlikely to be sufficiently competent to examine lifts incorporating current technology. Furthermore, whatever the qualifications of the individual, the organisational structure of the inspection body must be such as to ensure that examinations are carried out satisfactorily so that, for example, adequate time is allocated for the examination and the results are correctly recorded and interpreted. Further guidance on the criteria which an inspection body should satisfy is given in *ISO Guide 39*[18].

Within the UK, the National Certification of In-Service Inspection Bodies (NCISIB) scheme has been established to assess the competence of inspection bodies. The scheme is operated by the Engineering Inspection Authorities Board (EIAB) and is supported by the professional institutions, government departments, users and the major inspection organisations. Its aim is to establish the status of an inspection body's management system by comparison with quality criteria developed by the NCISIB Council and generally in accordance with the requirements of *BS 5750*[19] and *ISO Guide 39*[18].

12.4 Maintenance considerations

12.4.1 General

Maintenance of lifts and escalators must not be regarded as an optional extra nor should a 'breakdown only' approach be adopted. In addition to lifts being required to be of good mechanical construction, sound material and adequate strength, the statutory provisions extend to requiring them to be properly maintained. Preventative maintenance must be employed to preserve the operational integrity of the installation.

12.4.2 Maintenance contracts

Basically there are two types of contract within the lift and escalator industry:

- Contracts which provide for checking and lubrication only, repairs being subject to agreed further costs. These are more aptly called 'service contracts'.
- Contracts which provide for comprehensive maintenance and covering all parts, labour and call-out fees.

The service contract is best suited to organisations wishing to have direct control over maintenance including the resources available and the timing of repairs and/or replacements. However, many organisations find this a cumbersome procedure. For customers with in-house lift expertise, the major maintenance and service organisations now offer a 'tailored' service contract, which includes specified elements of the maintenance schedule.

The overall costs of both forms of contract should be similar. Unfortunately, the low initial cost of the service contract is often the sole deciding factor. Furthermore, the total budget for lift/escalator maintenance is sometimes determined solely on the cost of the service contract, 'non-essential' preventative works being regarded as unnecessary expenditure. This inevitably leads to poor performance, accelerated deterioration of equipment and premature failure.

Full maintenance contracts provide a regular budgeted cost and, where practicable, secure a predetermined performance level throughout the life of the installation. The on-going maintenance costs of lift/escalator systems must be considered an integral part of the operating costs of the building. In most cases, they are negotiable with the equipment manufacturer in the form of a long-term agreement. The longer the agreement period, the greater is the incentive for the contractor to develop effective programmes for maintenance work. Contracting the equipment manufacturer to provide the maintenance beyond the initial warranty period has inherent advantages in respect of product familiarity, particularly in terms of design, development and training.

The level of activity undertaken by the maintenance contractor varies according to the age and complexity of each installation, the equipment usage and the performance requirements. These factors determine not only the number of visits per year (which may range from two to twenty) but also the scope of work undertaken at each visit over, say, a five- or eight-year programme.

Detailed programmes of anticipated maintenance commitments are becoming more readily available to purchasers of new installations and should be requested within the appropriate specification. However, care should be taken if a maintenance programme produced by the manufacturer is imposed on the maintenance contractor as a contractual condition (particularly if the maintenance contractor is not the manufacturer). The manufacturer's programme may have been tentative and subject to amendment, even over the intended operational period.

The installation of performance data loggers, to either new or existing lift control systems, makes it feasible to specify maintenance requirements in terms of quantitative performance criteria. With such equipment, it is now comparatively simple to record and analyse performance data such as service and usage characteristics, number of failures over a specified period, mean time between failures, average/maximum service response time and system downtime/percentage system availability (see also section 10).

12.5 Quality assurance

12.5.1 General

The application of a formal approach to quality management has been proven to yield significant benefits and an increasing number of companies within the UK are adopting quality management systems.

In Britain, *BS 5750*[19] (based on *ISO 9000*[20] and adopted within Europe as *EN 29000*[21]) outlines the philosophical elements that must be considered for incorporation within a quality management system. The standard adopts a broad, generalised approach and the requirements, if interpreted rationally, are applicable within any industry, whether manufacturing or service based.

Registration with an independent certification body demonstrates that the quality management system complies with *BS 5750* in assuring effective control over consistent quality. Within the UK the competence of certification bodies is afforded specific credibility through an accreditation process administered by the Department of Trade and Industry via the National Accreditation Council for Certification Bodies (NACCB).

Similar systems exist in the Netherlands and, through the European Accreditation Council, are being developed throughout Europe together with schemes for mutual recognition of national arrangements. These networks are developing to support the European Community policy for a global approach towards the establishment of European quality assurance and product conformity systems.

Within the accredited certification bodies framework, two approaches exist. The first of these is an industry sector dedicated approach adopted by certification bodies which specialise in quality assurance for a particular industry. The alternative is a more general approach whereby a certification body covers a wide range of industrial sectors but specialises in a specific activity, e.g. manufacture, or in companies with some specific attribute, such as size.

12.5.2 Application to lifts and escalators

Within the UK lift and escalator industry, a scheme has been developed[22] to provide a mechanism for the common interpretation of *BS 5750* requirements through a balanced, independently chaired, governing board incorporating the interests of manufacturers, purchasers, insurers, and professional and governmental bodies without any single interest predominating. The result has been the publication of Quality Schedule Supplements (QSS) which provide a specific interpretation of general *BS 5750* requirements for each of ten identified types of organisation covering all aspects of the industry including manufacturing, maintenance and service, inspection and consultancy sectors.

When a company applies for certification under *BS 5750*, a team comprising both quality assurance and technical specialists assesses an applicant's quality management systems against the requirements of the applicable QSS. Following satisfactory completion of the assessment and the granting of registration, the integrity of the systems, including site and product-specific controls, is monitored twice yearly. Every fourth year, the system is subject to reassessment. Purchasers using manufacturers registered within *BS 5750* are assured of the enhanced control of factory production systems and, more importantly for lifts and escalators, site installation systems.

Certificates can incorporate, at the purchaser's option, additional Product Conformity Certification for individual installations, known as PCC(I), for individual installations. Under this scheme, the certifying body using the resources of an authorised inspection body (which is itself subject to independent assessment) closely monitors defined stages of production and/or installation. PCC(I) encompasses an appraisal of the specification and related drawings, surveillance during installation, witnessing of certain critical tests, thorough examination of the completed installation and provision of a comprehensive technical dossier. This dossier includes type test certificates (where appropriate), appropriate drawings, data and diagrams, a user manual including details of maintenance requirements for a period of not less than five years together with the report of thorough examination (i.e. F54 for lifts). The PCC(I) system covers the likely requirements for certification under a proposed EC Directive concerning lifts and similar person-lifting equipment.

The scope of *BS 5750* registration can be further extended by a conformity certification scheme for maintenance and service activities, known as PCC(M/S). This involves statistical monitoring of service activity and/or performance compliance against a common programme agreed by the industry. This is achieved by site verification of a sample of randomly selected contract installations against defined objective criteria.

References

1 *Health and Safety at Work etc. Act 1974* (London: HMSO) (1974)

2 *EN 81: Safety rules for the construction and installation of lifts and service lifts: Part 1: 1985: Electric lifts* (Brussels: Comité Européen de Normalisation) (1985) (adopted in UK as *BS 5655: Part 1: 1986*)

3 *EN 81: Safety rules for the construction and installation of lifts and service lifts: Part 2: 1987: Hydraulic lifts* (Brussels: Comité Européen de Normalisation) (1987) (adopted in UK as *BS 5655: Part 2: 1988*)

4 *BS 5655: Safety rules for the construction and installation of lifts and service lifts: Part 1: 1986: Electric lifts* (London: British Standards Institution) (1986)

5 *BS 5655: Safety rules for the construction and installation of lifts and service lifts: Part 2: 1988: Hydraulic lifts* (London: British Standards Institution) (1988)

6 *BS 5656: 1983: Safety rules for the construction and installation of escalators and passenger conveyors* (London: British Standards Institution) (1983)

7 *BS 5655: Safety rules for the construction and installation of lifts and service lifts: Part 10: 1986: Specification for the testing and inspection of electric and hydraulic lifts* (London: British Standards Institution) (1986)

8 Lifts: thorough examination and testing *HSE Plant and Machinery Guidance Note PM 7* (London: HMSO) (1982)

9 *Factories Act 1961* (London: HMSO) (1961)

10 *Offices, Shops and Railway Premises Act 1963* (London: HMSO) (1963)

11 Escalators: periodic thorough examination *HSE Plant and Machinery Guidance Note PM 45* (London: HMSO) (1984)

12 *The Hoists Exemption Order 1962 Statutory Instrument No. 715* (London: HMSO) (1962)

13 *Offices, Shops and Railway Premises (Hoists and Lifts) Regulations 1967 Statutory Instrument No. 849* (London: HMSO) (1967)

14 Safety at lift landings *HSE Plant and Machinery Guidance Note PM 26* (London: HMSO) (1981)

15 Safety in the use of escalators *HSE Plant and Machinery Guidance Note PM 34* (London: HMSO) (1983)

16 Passenger-carrying paternosters *HSE Plant and Machinery Guidance Note PM 8* (London: HMSO) (1977)

17 *EN 115: Safety rules for the construction and installation of escalators and passenger conveyors* (Brussels: Comité Européen de Normalisation) (adopted in UK as *BS 5656: 1983*)

18 General requirements for the acceptance of inspection bodies *ISO Guide 39* (Geneva: International Standards Organisation) (1988) (available in UK through BSI)

19 *BS 5750: Quality systems* (London: British Standards Institution)

20 *ISO 9000: Quality systems* (adopted in UK as *BS 5750*) (Geneva: International Standards Organisation)

21 *EN 29000: Quality systems* (adopted in UK as *BS 5750*) (Brussels: Comité Européen de Normalisation)

22 Day P H New innovations from the UK *Elevator Technology* 3 (Manchester: IAEE Publications) (1990)

Appendix A12.1: Typical test certificates and examination reports

O & K Escalators Limited

O&K

ESCALATOR TEST CERTIFICATE

Client: ______________ Escalator No: __________

Type: __________

Site Address: ______________________________

____

- -

Motor

Motor No: ______________ Type: __________

Volts: ________ Amps: ________ Frequency: ______ HZ

H.P.: ________ KW: ________ R.P.M.: ________

Starting Current: UP __________ DOWN __________

Running Current: UP __________ DOWN __________

Gear

Gear No.: ______________ Check Oil Level: ______

Step Chain

Oil and Grease: __________ Spring Measurement: ______

Adjustment of Entry Forks ____________

Handrail

Tension: ______________ Clearance: __________

Pressure Rollers: __________ Drive Chain: __________

Steps:

Check Tubes for Lateral Play: ______ Alignment with Combs: ______

Clearance to Skirting (Max. 7mm combined with 4mm on one side): ______

No. of Steps: __________ Clean Roller Track: __________

Brake

Stopping Distance UP: ________ mm DOWN: ________ mm

Grease

Lubricate all grease nipples: ______________________

- 1 -

Figure A12.1 Typical test certificate for an escalator (reproduced by courtesy of O&K Escalators Ltd)

O & K Escalators Limited

O&K

Combs

Check switch operation: ______ Clearance to steps (max 4mm): ______mm

Safety Circuit

Check switches for stopping escalator: ____________

Check for correct operation with L.E.D.: ____________

Broken chain device Left ________ Right ________

Handrail entry Top Left ________ Top Right ________

Bottom Left ________ Btm Right ________

Broken step device Top ________ Bottom ________

Comb switch device Top ________ Bottom ________

Emergency Stop device Top ________ Bottom ________

Stop Switch on yolk ______________________

Stop Switch in pit area Top ________ Bottom ________

Step blocking device ____________

Control Panel

Check operation of test leads ____________________

Check operation of key switch ____________________

Check 13 amp sockets ______________________

Motor Box Covers

Check for correct fitment within frame ______________

Check for correct alignment with comb carrier __________

Headguards

Are headguards required? YES / NO If yes, which type: ________

Fire Alarm

Is the link to fire alarm required? YES / NO
If yes, has this been tested: ______________

General Checks

Make random checks of fixing for guides, motor and gear etc. ______

Glass joints - Are glass joints parallel and of correct width ______

Check butt joints in aluminium ______________________

- 2 -

Figure A12.1 — *continued*

O & K Escalators Limited

Extras

Are any of the following fitted or will be required:-
If so, which type:-

Vertical Glass Infills ____________________

Child Deflector Panels ____________________

Check the operation of the following items, if fitted:-

Handrail Lighting ____________________

Automatic oiler ____________ Heater/Thermostat ____________

Fire Shutter ____________

Phase Failure ____________

Handrail drop device Left ____________ Right ____________

Skirting switch ____________________

Brake wear switch ____________ Brake Lift Switch ____________

MISSING ITEMS AT TEST

____

____

TESTERS COMMENTS

____

____

____

____

____

DATE: ____________ TESTED BY: ____________

The above tests and operations have been carried out in accordance with standing instructions, and the Escalator/Autowalk has today been handed over.

Signed ____________________

- 3 -

Figure A12.1 — *continued*

British Engine

Prescribed for the
Report of Examination of Hoist or Lift

The Offices, Shops and Railway Premises (Hoists and Lifts) Regulations 1968—Regulation 6
Factories Act 1961—Sections 22, 23 and 25
Factories Act (Northern Ireland) 1965—Sections 23, 24 and 26
Office and Shop Premisess Hoists and Lifts Regulations 1969. (Northern Ireland)—Regulation 6

IN ALL CORRESPONDENCE PLEASE QUOTE REFERENCES BELOW

L.RKL
LEC 9105207
21.2.91 8091872

Occupier (or Owner) of premises Address	A Company plc 1 The Market Place, Aytoun, Manchester
1a/ Type of Hoist or Lift and Identification Number and Description	Sch. No. L1 Electric Passenger and Goods Lift
b/ Date of Construction or Reconstruction (if ascertainable)	1982 by A Maker No. 21/2704

2 Design and Construction/ Are all parts of the hoist or lift of good mechanical construction, sound material and adequate strength (so far as ascertainable)? NOTE—Details of any renewals or alterations required should be given in (5) and (6) below. See 8

3 Maintenance/ Are the following parts of the hoist or lift properly maintained and in good working order? If not, state what defects have been found.

a/ Enclosure of hoistway or liftway	Yes	b/ Landing gates and cage gate(s)	Yes
c/ Interlocks on the landing gates and cage gate(s)	Yes	d/ Other gate fastenings	Yes
e/ Cage or platform and fittings, cage guides, buffers, interior of the hoistway or liftway	No - See 6	f/ Over-running devices	No - See 5
g/ Suspension ropes or chains, and their attachments	See 8	h/ Safety gear, i.e. arrangements for preventing fall of platform or cage	Yes
j/ Brakes	Yes	k/ Worm or spur gearing	No - See 6
l/ Other electrical equipment	Yes	m/ Other parts	Yes

4 What parts (if any) were inaccessible: Enclosed electrical and mechanical parts

5 Repairs, renewals or alterations required to enable the hoist or lift to continue to be used with safety—
a/ immediately
b/ within a specified time, the time to be stated.
If no such repairs, renewals or alterations are required enter "NONE"

a/(f) Operating lever on ultimate limit switch slack and displaced and requires to be reset forthwith. (Site Manager is understood to have initiated appropriate repair via service company).
b/ None

6 Defects (other than those specified at 5 above), which require attention

(e) Liftway interior ledges excessively soiled with a build up of dust and lint - to be suitably cleaned
(k) The gearbox is leaking and should receive attention

7 Maximum safe working load subject to repairs, renewals or alterations (if any) specified at (5): 14 persons or 2240 lbs. as marked

8 Other observations

Design not checked - construction sound as far as could be ascertainable at this inspection.

(g) Suspension ropes contain 6 broken wires evenly distributed over a length equivalent to 6 diameters and whilst serviceable at

PTO

I certify that on .... I thoroughly examined this hoist or lift and that the foregoing is a correct report of the result.

Signature [signature] Date 21.2.91

Qualification : Engineer Surveyor to
BRITISH ENGINE INSURANCE LTD.
Longridge House
Manchester M60 4DT
Telephone : 061-833 9282

To be attached to the General Register

LC 54 (10003) BE14404'87 BE103

Figure A12.2 Typical lift examination report (Form F54) (reproduced by courtesy of British Engine Ltd)

SPACE FOR CONTINUATION OF ENTRIES

8 (g) Continued

present consideration should be given to their replacement at a convenient time over the next 12 month period.

The safety gear operational test will be due November this year (last record 11/86).

On arranging rope replacement it may be prudent to simultaneously arrange to (i) carry out safety gear test (ii) open up worm gear for close inspection of enclosed parts, (iii) expose pulley shafts and bearings for examination (iv) effect suitable repair to stem oil leak.

NOTES

The Factories Act 1961, Factories Act (Northern Ireland) 1965, the Offices, Shops and Railway Premises (Hoists and Lifts) Regulations 1968 and the Office and Shops Premises Hoists and Lifts Regulations, 1969 (Northern Ireland) provide that every hoist or lift shall be thoroughly examined by a competent person:

a/ in the casae of a continuous hoist or lift or a hoist or lift not connected with mechanical power—at least once in every period of twelve months.

b/ in the case of other hoists or lifts—at least once in every period of six months

A report of the result of every such examination is required in this prescribed form.

In premises where the Factories Act applies this form must be attached to the General Register. Otherwise it must be kept available for inspection for a period of two years.

When the examination shows that the hoist or lift cannot be used with safety unless certain repairs are carried out immediately or within a specified time, a copy of the report must be sent to the appropriate enforcing authority, i.e. the District Inspector of Factories, the District Inspector of Mines and Quarries or the local authority, within 28 days of the completion of the examination.

Figure A12.2 — *continued*

NATIONAL VULCAN

REPORT OF EXAMINATION OF ESCALATOR

L999

In any correspondence relating to this report please quote: G116756/11

Occupier (or Owner) of premises	A A L Group PLC
1 Address	1 High Street Goostree Cheshire
2 (a) Type of installation and identification number and description	No.699871335 (First to Second) ELECTRIC ESCALATOR
(b) Date of construction or re-construction (if ascertainable)	1987
3 Design and Construction Are all parts of the installation of good mechanical construction, sound material and adequate strength (so far as is ascertainable)? Note:– Details of any renewals or alterations required should be given in (6) and (7) below.	Design not checked and construction sound so far as can be ascertained at this inspection
4 Maintenance Are the following parts of the installation properly maintained and in good working order? If not, state what defects have been found:	Yes, except as stated below:
(a) Balustrades (including gaps between steps and skirting).	Clearances between treadway and skirting are excessive. Guard panel adjacent to balustrade at escalator entrance is not fully secured.
(b) Treadway	-)
(c) Treadway interconnections	
(d) Combplates and terminal guides	–
(e) Overspeed governor	–
(f) Emergency stop switch(es)	–
(g) Broken chain device	–
(h) Broken drive device	–
(i) Non-reversal device	–
(k) Brakes	–
(l) Worm or spur gearing	–
(m) Chains	–
(n) Other electrical equipment (including insulation etc.)	–
(o) Balustrades skirting deflector devices	–
(p) Other parts	–
5 What parts (if any) were inaccessible?	Interior of wormgear, motor & brake (enclosed type)
6 Repairs, renewals or alterations required to enable the installation to continue to be used with safety:- (a) immediately (b) within a specified time, the said time to be stated. If no such repairs, renewals or alterations are required enter "NONE"	(a) Clearances between treadway and skirting do not comply with those recommended in BS5656. This condition should be refered to your service engineers for action. (b) None
7 Defects (other than those specified at 6 above) which require attention	Secure loose guard panel
8 This equipment is considered safe to operate subject to repairs, renewals or alterations (if any) specified at 6.	Yes.
9 Other observations	Continued overleaf.....

10

I certify that on 20.05.91. I thoroughly examined this installation and that the foregoing is a correct report of the result.

Signature [signature]   Date 20.05.91.

Qualification – Engineer Surveyor to
National Vulcan Engineering Insurance Group Limited
St. Mary's Parsonage, Manchester M60 9AP.
Telephone: 061-834 8124. Telex: 667955 Boiler G. Fax: 061-834 2394

L55J (3/91)

Figure A12.3 Typical escalator examination report form (reproduced by courtesy of National Vulcan Engineering Insurance Group Ltd)

9 Other Observations...

Missing pictographs at escalator entrance should be replaced.

We advise that suitable guards be fitted at the intersection of the escalator deckboard with the underside of adjacent machine to prevent possible trapping hazard.

At this inspection the escalator was examined at work and rest only with no parts opened out. We request that arrangements be made for our engineer surveyor to be in attendance at the time of your engineers next major service when a number of steps will be removed and access traps raised. in order that a thorough examination of all areas of machinery can be made.

Figure A12.3 — *continued*

13 Modernisation of lift installations

Principal author

A Shiner (Kone Lifts Ltd)

Acknowledgements

S Gray (Geoffrey Wilkinson (City) Ltd)
G Honey (The Gerald Honey Partnership)
W H Westmoreland (Norwich Union Insurance Group)

Contents

13 Modernisation of lift installations

13.1 General

Typically lift installations require modernisation between 15 and 20 years after initial installation. In some cases, e.g. where an inadequate specification or design has resulted in a lift system that is not suited to the building needs, modernisation may be necessary as early as five years after installation.

The reasons for modernising lifts are varied and include:

- poor reliability
- spare parts unavailable or difficult to obtain
- poor lift service with low traffic handling capability
- traffic or group control system no longer suitable due to change in use of the building
- lift modernisation required as part of building refurbishment
- to bring installation up to requirements of latest British Standards and/or health and safety at work legislation.

Often, lift performance can be improved by modernising some components of the lift. In this way, full modernisation can be programmed over a period of several years. This is a useful option where budgets are fixed and insufficient funds are available for complete modernisation. The modernisation overlay technique uses this approach to minimise disruption during modernisation of large lift groups.

Typically the components which can be modernised in this way are:

- car interior
- car operating panel
- call pushes and indicators (depending on existing equipment)
- safety edges and passenger detectors
- door operators
- drive (e.g. replacement of single- or two-speed AC motor drive to a controlled AC variable voltage or variable voltage variable frequency drive using a self-contained 'add-on' drive)
- traffic or group controller
- well equipment.

Account must be taken of *BS 5655: Part 11*[1] regarding items which must be upgraded under a modernisation program.

13.2 Modernisation overlay technique

Applicable primarily to four-car lift groups or larger, the overlay technique allows modernisation of lifts with minimal disruption to building users, while maintaining lift service during the short period that work is carried out on site.

The modernisation is carried out in two stages. The interval between implementation of stages 1 and 2 may be chosen to suit the particular circumstances. This allows building owners flexibility in planning according to condition of the lift equipment, available funding and other refurbishment programmes for the building.

13.2.1 Stage 1

Stage 1 may be regarded as 'first aid', i.e. a temporary means of improving the efficiency of the lift installation, and enables full modernisation to be carried out without noticeable disruption to the lift service.

New computer-based group control is installed to provide efficient handling of the landing calls under all traffic conditions. It is connected to each of the old lift controllers by means of a separate 'adaptor' computer. The adaptor computer controls the old lift drive and doors and also provides the new computer-based group controller with information on the status of the lift.

Installation of this new equipment in the machine room does not affect the old lift system. The connection of the adaptor computers to the old lift controllers takes place in phases with an average down-time of two to three days, or less, for each lift.

On completion of this stage, the new group control can improve the traffic handling capacity of the installation by 20–25%. It increases the reliability of the installation by reducing the number of relays in operation in the old traffic or group control panels.

13.2.2 Stage 2

The individual traffic or group controllers and motor drives are replaced, one at a time, using the new lift control system. This process necessarily takes several weeks, during which individual lifts are shut down and taken out of service one at a time. Often, the car interiors, hall and car indicators, call pushes and doors are refurbished at the same time.

When all the new controllers have been installed, call waiting times can improve by 30–50% and excessively long waiting times may be virtually eliminated.

13.3 Estimation and measurement of performance

Full modernisation of a group of lifts is expensive. It is essential that performance appraisals are undertaken both before and after modernisation.

Accurate measurements of the group performance of the existing installation can be made by computer using on-site traffic surveys. Most major lift companies and engineering consultancies have their own computer programs to calculate group performance (i.e. traffic handling performance), see section 3 and 11. The performance after the modernisation can be predicted by using these measurements in conjunction with the performance parameters of the new equipment and the building usage.

Most lift companies and consultants are able to provide this service. If predictions of performance are sought from several manufacturers, it is essential to check carefully the parameters and assumptions made in these predictions.

Reference

1 *BS 5655: Lifts and service lifts: Part 11: 1979: Specification for modernisation and reconstruction* (London: British Standards Institution) (1979)

14 Glossary of terms

Principal author

G C Barney (Lerch, Bates and Associates; UMIST)

Acknowledgements

International Association of Elevator Engineers

14 Glossary of terms

The majority of the terms in this glossary have been drawn from *Elevator Micropedia*† by kind permission of The International Association of Elevator Engineers. Requests for information concerning the authority of the terms defined, cross-references and other terms not included here should be made to the IAEE.

Note: The terms are arranged in noun order for convenience e.g. 'express zone terminal floor' is given as *floor, express zone terminal* and 'oil buffer stroke' is given as *stroke, oil buffer*.

Acceleration

The rate of change of velocity with time, usually not exceeding 1.5 m/s^2 for lift systems.

Access doors

Means of access to equipment areas and other spaces pertaining to a lift installation such as machine rooms, overhead machine spaces, etc. and with access usually restricted to authorised persons.

Acoustic noise

Noise which is airborne emanating from lift components such as drive machines, control equipment, movement of guide shoes on rails, etc.

Adjuster

A lift technician, who carries out the final inspection of new and modernised installations to ensure that all the equipment has been properly installed and set up according to specification.

Air bleed

A device which allows the release of trapped air in the fluid system of an hydraulic lift.

Air cord

Part of the driving mechanism of a door operator, which is made from a small diameter wire rope.

† *Elevator Micropedia* by G C Barney. Published by The International Association of Elevator Engineers, IAEE Publications, 9 Walmer Drive, Bramhill, Stockport SK7 3AT, England.

Alarm system

An emergency system installed on all cars, which comprises a bell, a pushbutton installed in the car and an uninterruptible source of power (usually a battery).

Algorithm

A set of rules, to which a system (often a control system) must conform.

Algorithm, group supervisory control

A set of rules defining the control policy that must be obeyed by a lift supervisory control system in order that it may pick up passengers from their arrival floors and transport them to their desired destination floors.

Angle of wrap

The proportion of a sheave, which is in contact with the suspension ropes, measured in degrees of contact.

Annunciator

A signalling device, which provides passengers with information regarding lift car position, etc. by means of indicator lamps.

Anti-creep

A feature found on hydraulic lifts that prevents the car from changing its relative position with respect to the landing floor by compensating for any leakage of oil.

Anti-nuisance device

A device found on some supervisory control systems, whereby the number of passengers in the car are determined, and compared to the number of calls registered, in order that unnecessary trips are prevented.

Application specific integrated circuit (ASIC)

An electronic circuit designed for a specific purpose by an equipment manufacturer.

Apron, car

A guard installed onto the underside of a lift car, which utilises advance door opening, to prevent the trapping of objects or passenger limbs, whilst a descending car is levelling at a landing.

Architrave

The various parts surrounding a doorway in order to present a neat appearance; a moulding.

Armature

The rotor or moving part of a direct current (DC) machine.

Arrow, down

An illuminated arrow symbol either mounted in the rear of a lift car, or mounted above or alongside the car entrance, or both, which indicates to intending passengers the direction of travel of the arriving car is to be in the downward direction.

Arrow, up

An illuminated arrow indicating an upward travelling car in a similar fashion to a down arrow.

Astragal

A moulding, usually made of rubber or metal, on the leading edge of hoistway and car doors and extending the full height on centre-opening doors or the full width of bi-parting doors, in order to reduce the effects of injury should the doors touch a passenger and to quieten door operation.

Astragal, safety

A resilient, incompressible safe edge mounted onto the bottom of the upper section of a bi-parting hoistway door of a freight lift.

Attendant

A person who is permanently located in the lift car in order that passengers do not need to operate the controls, such as the car switch (in older systems), destination pushbuttons, and car/hoistway doors (in manual systems).

Automatic bypass

A feature of a lift supervisory control system, which causes the lift car to automatically bypass landing calls under certain circumstances, such as when a car is fully loaded and has no room for further passengers, or a car is making a special trip to serve a demand at a distant floor, e.g. lobby service, heavy demand call etc.

Automatic control

A generic term, used to define any error-activated, power amplifying, negative feedback, closed loop control system.

Automatic pushbutton control

A term used to define the simplest means of automatically controlling a single car, where a car may be called to a floor by the pushing of a landing pushbutton (provided it is not already busy) and commanded to travel to a destination floor by the operation of a car call pushbutton.

Average car load

The total number of passengers carried in one direction of travel, divided by the number of trips in that direction, averaged over a certain time period, usually taken as five minutes, hence up-peak or down-peak average car load.

Babbitt

Soft alloy of tin, antimony, and copper used as an anti-friction material for the socketing of wire ropes for lifts.

Balanced traffic

A term used in connection with the interfloor traffic condition to indicate that the traffic flows in both up and down directions are substantially equal.

Bank

A number of groups of cars placed physically together, with each group serving a particular zone of a building. More than one group may serve the same zone and it is possible to have a bank comprising one group only.

Bar lock

Type of interlock used with manually operated doors.

Basement service

Service provided to a floor or floors below the main terminal in a building, which may be restricted at times in order to improve the service to other parts of the building.

Bed-plate

The foundation or support to which the hoist machine is attached, usually made of steel beams; a pedestal.

Bell, alarm

A bell, located either in the hoistway, or on a suitable landing, or on the car which, when operated by a passenger pressing a pushbutton inside the car, is used to call attention and assistance.

Bell, arrival

A bell either mounted on the lift car or as part of a fixture on the landing, which signals the arrival of the car at a floor, where it is to pick up passengers.

Bi-parting doors

Consist of two counterweighted panels, which slide vertically, one in the upward direction and one in the downward direction, interconnected so as to move in synchronisation, and strongly constructed to facilitate their use in freight lifts (goods lifts).

Borehole

A vertical hole bored in the lift pit to accommodate the cylinder assembly of a hydraulic lift.

Borehole liner

Rigid capped tube inserted in the borehole of a hydraulic lift to prevent its collapse or the ingress of water.

Bottom run-by, car

When a lift car is level with the bottom terminal landing, the car bottom run-by is the distance between the striking surface of the car buffer and the car buffer striker plate.

Bottom run-by, counterweight

When a lift car is level with the upper terminal landing, the counterweight bottom run-by is the distance between the striking surface of the counterweight buffer and the counterweight buffer striker plate.

Box, halfway

Box mounted in the hoistway near the halfway point of car travel to which the stationary ends of the travelling cable(s) are attached.

Brake

An electromechanical device, consisting of a spring assembly, which is held in compression by the energising of an electromagnet, and which holds the friction shoes from contact with the brake drum or disc, thus allowing the lift car to move. In the event of the car exceeding its rated speed, or a power failure, or a control system demand to hold the car stationary, the brake is de-energised and the brake operated, thus stopping the car in a safe distance or holding the car in position.

Brake drum

A smooth surface usually mounted on the hoist machine drive shaft, with which the brake shoes make contact whenever the brake magnet is de-energised, in order to absorb the energy of motion.

Brake lining

Material used to line brake shoes, which has a high co-efficient of friction.

Brake magnet

A magnet usually provided in the form of a solenoid, which is used to cause the brake shoes to move away from the brake drum, whenever it is energised.

Brake shoe

The moving component of a brake, to which the brake linings are fixed and which, when in contact with the brake drum, causes a lift car to be brought to rest.

Bridge

An electrical or electronic circuit which maximises power conversion efficiency between AC and DC supplies in either direction.

Buffer

Device capable of absorbing the kinetic energy of motion of a descending car or counterweight, when they have passed a normal limit of travel, by providing a resilient stop, and comprising a means of braking using fluids or springs (or similar means).

Buffer, car

A final emergency device to bring a lift car to rest by absorbing the energy of motion should the car pass the normal downward limit of travel.

Buffer, counterweight

A final emergency device to bring a counterweight to rest by absorbing the energy of motion should the counter-weight pass the normal downward limit of travel.

Buffer, energy accumulation type

A buffer where the kinetic energy of motion is stored in the gradual compression of a spring, which provides a progressive retarding force.

Buffer, energy dissipation type

A buffer where the kinetic energy of motion is dissipated, by converting the energy into heat by the flow of oil through a series of holes and hence applying a constant force for retardation.

Buffer, oil

An energy dissipation type of buffer.

Buffer return spring

Spring used to return an energy dissipation type of buffer back to its operating position.

Buffer, spring

An energy accumulation type of buffer.

Buffer, stroke

The distance that a buffer can be compressed.

Buffer switch

(*a*) A switch that is activated to remove power to the lift drive system should a buffer be operated; (*b*) a switch that is activated to prevent further operation of the lift should the oil in an oil buffer fall below some minimum allowable level.

Building, commercial

A building in which people work such as an office, store, factory.

Building, institutional

A building in which people receive a service such as a hospital, school, university, public building.

Building, residential

A building in which people live such as a houses, hotel, flat, hostel.

Bumper

Device other than a spring or oil buffer capable of absorbing the kinetic energy of motion of a descending car or counterweight, when they have passed a normal limit of travel.

Bunching

A traffic pattern where several lifts move in conjunction, rather than being separated evenly; often caused by a sudden heavy traffic demand or an inadequate traffic supervisory system.

Bypass floors

Floors, which are bypassed in a building, as a result of a supervisory control action or because the car is fully loaded.

Bypass valve

Valve, which diverts the pump output from the fluid power line to the fluid storage tank, of a hydraulic lift.

Cab

That part of a lift car comprising a self-contained enclosure, mounted on a lift platform, in which passengers or goods are carried.

Cable, travelling

A cable made up of electrical conductors, which trails behind the car of a lift, dumb waiter or material lift to provide an electrical connection between the car and a fixed outlet in the hoistway or machine room. Sometimes called trailing cable.

Call

A demand for service by a passenger, which is entered into a lift supervisory control system by the passenger pressing either a landing or car call pushbutton.

Call accepted

The acceptance of a landing or car call by a lift supervisory control system.

Call accepted indicator

An indicator contained within or adjacent to a landing or car call pushbutton, which is illuminated by a lift supervisory control system when it accepts a call.

Call allocation

The action of a lift supervisory control system when allocating a landing call to a specific car for service.

Call back

A service visit, at the request of a lift operator, made by a lift maintenance technician, which is not scheduled and which arises because the lift has gone out of service owing to a fault condition.

Call, car

A passenger demand registered from within a car requesting that the car stop at a specified landing.

Call, down

A passenger demand registered on a landing, requesting transportation by a lift in the down direction.

Call, highest reversal

The highest landing that a lift visits during a trip in the upward direction before reversing its direction of travel.

Call, intensive duty

In some circumstances a landing call is given extra emphasis by the lift supervisory control system when either (*a*) a new landing call is registered within a short, predefined time, (*b*) several cars have left the floor fully loaded or (*c*) too many landing and car calls have been assigned to a single car, thus requiring the supervisory control system to take special priority action.

Call, landing

A passenger demand registered on a pushbutton on a landing for transportation to other floors in a building.

Call, lowest reversal

The lowest landing a lift visits during a trip in the downward direction before reversing its direction of travel.

Call memory

Part of a lift supervisory control system, where all landing and car calls are stored before being serviced.

Call pushbutton

A pushbutton situated either in a car or on a landing, on which passengers may indicate their travelling intentions.

Call registration

The action of registering a call.

Call, up

A passenger demand registered on a landing, requesting transportation by a lift in the up direction.

Cam

Piece of machinery used to convert linear motion into circular motion employed in lift installations to operate (*a*) hoistway door interlocks, (*b*) hoistway floor selectors, (*c*) car-mounted terminal switches, (*d*) hoistway-mounted terminal switches.

Cam, door

Device mounted on a car door and used to unlock and drive the landing doors; also known as the vane.

Cam, retiring

A cam mounted on a lift car, which remains in a retracted or retired position, whilst the car is moving, until the car is about to stop, when it drops, in order to unlock the landing door interlock.

Canopy

The top of a lift cab, which is supported by the walls and contains the ceiling.

Car

The load carrying unit comprising enclosure (cab), car frame, platform and door(s).

Car allocation

The action of a lift supervisory control system when allocating a specific car to a set of landing calls for service.

Car counterweight

A counterweight roped directly to the car in a drum drive installation and approximately equal to 70% of the weight of the car.

Car despatch

A term used to indicate the type of supervisory control system employed, where cars are despatched from terminal floors in a building at scheduled intervals.

Car, free

A car to which the supervisory control system has not allocated any further calls and is therefore free to be given a new assignment.

Car isolation

The isolation of the car platform by means of rubber or other sound absorbing material in order to reduce or absorb the transmission of vibration and noise.

Car, rear opening

Where the car is furnished with doors at the rear of the car in addition to the normal doors provided at the front.

Car, side opening

Where the car is furnished with doors at the side of the car in addition to the normal doors provided at the front.

Car top

The top of the car enclosure.

Chain

Connected flexible series of metal or other links.

Chain, compensating

A chain used to offset the varying effect of the hoisting ropes, one end of which is attached to the underside of the car and the other to the counterweight or to a fixed point in the hoistway.

Chain drive

Alternative means of suspension to wire ropes for electric and hydraulic lifts.

Chain drive machine

An indirect drive machine having a chain connecting the driving motor to the drive sheave.

Cill

See *sill*.

Circulation

The process by which persons in a building move around the building in both horizontal and vertical modes.

Clearance

The space by which one object avoids contact with another object.

Clearance, bottom car

When the lift car rests on its fully compressed buffers, the bottom car clearance is the clear vertical distance from the pit floor to the lowest structural part, mechanical part, equipment or device installed beneath the car platform, with the exception of guide shoes, guide rollers, safety jaw assemblies, platform aprons and platform guards.

Clearance, top car

When the car floor is level with the top terminal landing floor, the top car clearance is the shortest vertical distance between the top of the car crosshead, or car top if no crosshead is provided, and the nearest part of the overhead structure or any other obstruction.

Clearance, counterweight top

When the lift car floor is level with the bottom landing floor the top counterweight clearance is the shortest distance between any part of the counterweight structure and the nearest part of the overhead structure or any other obstruction.

Clearance, running

The distance between the lift car sill and the hoistway entrance sill.

Closer, car door

A mechanical device attached to a car door whose function is to ensure the car door automatically closes after use, using the stored energy in a set of weights or a spring.

Code

A system of rules or regulations; also known as a standard.

Commutation, thyristor

The process of transferring the conduction of current from one thyristor to another.

Computer-aided design (CAD)

A system where a digital computer carries out the tedious and time-consuming aspects of an engineering design.

Contact, door

An electric switch device operated by a door panel, which is closed when the door panel is in the closed position, allowing the operation of the lift car.

Contact, gate

A mechanically operated switch, which prevents the operation of the lift unless the lift gate is closed.

Contract capacity

See *rated load*.

Contract speed

See *rated speed*.

Control, AC

A form of motion control achieved by the use of an AC motor to drive the hoist machine.

Control, attendant

Where the direction of travel, door closing and car starting are under the control of an attendant.

Control, automatic pushbutton

Where the travelling passengers are able to command a lift car to move from floor to floor without the need of an attendant, as door control and car direction and starting are all automatic.

Control, closed loop

A control technique which gives accurate control of a parameter by comparing the actual parameter with a reference value to generate an error signal, which is then used to apply corrective action.

Control, DC

A form of motion control achieved by the use of a DC motor to drive the hoist machine.

Control, directional collective

Where landing calls are registered on a set of up and down landing call push buttons, the landing and car calls being registered in any order but are answered strictly in floor sequence in the direction of travel, taking account of the direction of travel of the registered landing calls.

Control, door

The control system which opens and closes the car and landing doors of a lift installation.

Control, drive

The system which controls the starting, stopping, direction of motion, acceleration, retardation, and speed of the lift car.

Control, group collective

A simple form of group control system, where two (duplex) or three (triplex) cars are interconnected and collectively controlled, but providing a means of allocation of the best placed car to each landing call.

Control, group supervisory

A control system which commands a group of interconnected lift cars with the aim of improving the lift system performance.

Control, non-collective

The simplest form of control whereby a car will only answer a landing call if it is available.

Control, on-call

A lift supervisory control system where cars are despatched to serve landing calls according to a fixed or tunable algorithm.

Control, scheduled

A lift supervisory control system where cars are despatched to serve landing calls according to a fixed schedule from terminal floors.

Control, simplex collective

Where landing calls are registered on a single set of landing call push buttons, and landing and car calls may be registered in any order, but are answered strictly in floor sequence in the direction of travel, passengers being unable to indicate their desired direction of travel; also known as non-selective control.

Control, supervisory

An open loop control system which is used to manage a plant or process, such as a lift traffic control system.

Control, up-distributive down-collective

Where a single set of landing push buttons indicate a down demand on floors within a building, thus allowing the lift system to distribute ascending passengers when travelling upwards and to collect descending passengers when travelling downwards.

Controller

A controlling device.

Controller, programmable

A controlling device which can have its operating rules altered by means of a program.

Cord, air

A small diameter wire rope frequently used as part of the driving mechanism on door operators, door hangers, gates and selector devices; also known as aircraft cable.

Corridor

A passage or covered way between two places.

Counterweight

A component which is employed to ensure traction between the drive sheave and the suspension ropes and which comprises a set of weights to balance the weight of the car and a proportion of the load in the car, often taken as 50% of the contract load.

Counterweight, car

A counterweight, which is directly roped to the lift car on a winding drum installation and which is approximately 70% of the car weight.

Counterweight filler

A metal component of predetermined size and weight which when stacked with other fillers in the counterweight frame forms the counterweight assembly.

Counterweight guard

A screen installed in the pit, and sometimes at the mid-point of the hoistway, to prevent persons from encroaching into the counterweight runway space.

Counterweight, guide rails

Steel T-shaped sections which guide the counterweight in its vertical travel in the hoistway.

Counterweight header

A weight component larger than a standard filler, which extends around the counterweight guide rails and guides the counterweight.

Counterweight safety

A mechanical device attached to the counterweight frame designed to stop and hold the counterweight in the event of an overspeed or free fall or the slackening of the suspension ropes.

Crown bar

The upper member of the car frame of a lift car.

Cylinder

The outermost lining of a hydraulic jack.

Cylinder (displacement type)

A single-acting cylinder where the cylinder ram is sealed at the cylinder gland against fluid losses and where the output force is proportional to the ram area.

Cylinder (piston type)

A single-acting or double-acting cylinder, where the piston, which is attached to the cylinder ram, seals against the inside of the bore of the cylinder tube and where the output force is proportional to the piston area in one direction and to the piston area minus the ram area in the other direction.

Cylinder gland

The seal used to prevent loss of fluid.

Damper

Common expression referring to a shock absorber.

Dashpot

A mechanical device comprising a piston moving in a cylinder against air or oil, used to control or cushion the movement of an arm, lever or rod; particularly those used to prevent the slamming of doors.

Data-logging

The process of logging (acquiring) and analysing data automatically using digital computer-based equipment.

Decibel, acoustic

A logarithmic scale for measuring sound intensity.

Detector, passenger

An automatic electronic device, which causes door re-opening whenever a passenger is detected in the threshold using photoelectric, electromagnetic, electrostatic or ultrasonic detection methods.

Device, anti-nuisance

A device which attempts to reduce the effect of mischievous or malicious passengers registering more car calls than there are passengers in the car or attempting to send a car away when no passengers are present in the car.

Device, door re-opening

A device which detects the obstruction of automatic power doors and causes them to either re-open or go into another mode of operation such as nudging.

Device, levelling

A mechanism, which will move a lift car, when it is in the levelling zone, at a reduced speed towards a landing and stop it there.

Device, signalling

An annunciator (light, indicator, bell, buzzer, etc.), which provides information to passengers about car direction, car position, car arrival, call acceptance etc.

Diversity factor

A factor which may be applied to reduce the sizing of services, for example electric power cables, on the basis of a mathematical probability that not all connected equipment will require serving at the same time.

Dividing screen

Screen installed between the paths of travel of two lifts sharing the same hoistway to enable the safe working on one lift whilst the other lift is still operational.

Door

The movable portions of the car or hoistway entrance, which control the safe access to and from the moving car.

Door, access

A door which provides access to equipment and machinery spaces such as; hoistways, pits, machine rooms, overheads, etc.

Door, advance opening

The initiation of door opening whilst a car is slowing down when approaching a floor, under normal operating conditions, usually when the car is in a door zone of plus or minus 30 cm of floor level and so that the car is substantially level at the floor before passengers can attempt to exit.

Doors, bi-parting

A vertically sliding door, often found on freight lifts, which consists of two sections, so interconnected that they open simultaneously away from each other.

Door, car

The door, which is part of the passenger carrying enclosure, and serves to protect passengers from contact with the hoistway walls and equipment.

Doors, centre-opening

A horizontally sliding door, with two or more panels interconnected so that they open simultaneously away from each other.

Door, hoistway

The door sealing access to the hoistway from the landing floors.

Door, multiple panel (leaf)

Door(s) comprising two or more panels which are arranged to telescope behind each other as the door(s) opens.

Door, side-opening

A single or multiple panel, horizontally sliding door.

Door, single panel (leaf)

A horizontally sliding, side-opening door comprising a single leaf.

Door, two-speed

An arrangement, for either side- or centre-opening doors, where one panel slides behind the other panel at twice the speed, in order that both panels arrive at the opening position simultaneously.

Down-peak

A down-peak traffic condition exists, when the dominant or only traffic flow is in the downward direction, with all or the majority of the passengers leaving the building at the main terminal floor of the building.

Drive, direct

A drive where the driving part is directly connected to the driven part, either with or without intermediate gears.

Drive, drum

A positive drive system whereby the car and the counterweight are secured to a multi-grooved drum, so that as one set of ropes unwinds from the drum the other set winds on.

Drive, indirect

A drive system where the driving part is connected to the driven part by means of V-belts, tooth drive belts, or drive chains.

Drive-unit

A power unit which provides the means for raising and lowering the car and which comprises: an electric motor or hydraulic power unit; gearing; brake; sheave or drum; couplings and bedplate.

Drum

The cylinder of a drum-type driving machine, on which the hoisting ropes wind and unwind, when raising or lowering the lift car.

Dumb waiter

A lift used for the vertical transportation of materials only, comprising a car whose dimensions prevent the transportation of passengers and which moves in guides, often situated beneath a counter or sited at counter top level.

Duplex

Two interconnected cars, sharing a common signalling system, controlled under a simple group control system operating under directional collective principles.

Enclosure, car

The top and the walls of the car resting on and attached to the car platform.

Encoder shaft

A rotary digital encoder, which when rotated by a toothed tape attached to the car can provide a very accurate value for the position of a car in a hoistway as a binary number.

Entrance, car

The protective assembly which closes the hoistway enclosure openings normally used for entrance to and exit from the car.

Error

An event which is not fatal to the operation of a lift system, but which could result in degradation, malfunction, interruption or failure and which should be corrected as soon as possible.

Escalator

A power-driven moving stairway inclined at between 30° and 35° for the short range upward and downward transportation of passengers.

Event

Any occurrence envisaged in a design and defined as a recordable phenomenon.

Express-run

When a car makes a non-stop run from its current floor to a destination floor ignoring any possible stopping floors on the trip.

Failure

An event which results in a lift system becoming unserviceable.

Fault

A defect or imperfection, including failures and errors.

Fan, car

A means of mechanically ventilating the passenger car enclosure of a lift, aiding the air movement through the vent openings provided.

Filter, electrical

A circuit designed to attenuate or remove certain frequency components or spurious electrical noise from a signal or power supply.

Fishplate

A flat steel plate, which is machined on one side, used to connect together, in rigid alignment, two end-to-end sections of guide rail.

Fixture

Term used to denote a variety of signalling and indicating devices, such as landing and car call pushbuttons, position indicators, direction indicators, card access devices etc.

Fixture, intelligent

A fixture, commonly the car operating panel or lobby call registration panel, which has the ability to present information to passengers in an interactive manner and which may be able to process its input/output via a computer communication bus instead of via a multi-pair travelling cable.

Fixture, talking

A fixture which is programmed to provide passengers with information by means of a simulated speech output.

Fleet angle

Angle of deviation at which the rope leaves the centre of the sheave groove, usually less than two degrees.

Floating power supply

A power supply which has no connection to the electrical ground or any other supply in the equipment which it is supplying.

Floor, bottom terminal

Lowest floor in a building zone from which lift cars can load and unload passengers.

Floor, bypass

Floors at which a landing call has been registered, but which are passed by the lift car under circumstances when the car is fully loaded (load bypass) or when the car has other higher priority duties to perform (control bypass).

Floor, car

The under-surface of the interior of a lift car, on which passengers stand.

Floor, dispatch

Floors in a lift zone, often the terminal floors, from which cars are dispatched under the control of the scheduling supervisory control system.

Floor, express zone terminal

The lowest floor of a high rise zone in a building which is served by a lift car after it leaves the main terminal floor.

Floor, heavy duty

A floor at which a considerably larger than average number of passengers are demanding service, often detected by successive cars leaving the floor fully loaded or the immediate re-registration of a landing call as soon as a car has left a floor.

Floor, highest reversal

The floor at which a car reverses direction, when travelling in an upward direction having completed its last car call, in preparation to serve registered down landing calls.

Floor, lowest reversal

The floor at which a car reverses direction, when travelling in a downward direction having completed its last car call, in preparation to serve registered up landing calls, particularly during an interfloor traffic condition.

Floor, main

The main or principal floor of a building.

Floor, parking

A floor at which a lift car is parked when it has completed serving its car calls and the supervisory control system does not reallocate it to serve further landing calls.

Floor, terminal

The highest and lowest floors at the extremities of travel of a lift car within a building zone.

Floor, top terminal

Highest floor in a building zone from which lift cars can load and unload passengers.

Frame, car

A supporting frame consisting of stiles, crosshead, safety plank and platform to which the guide shoes, car safety and hoisting ropes or hydraulic plunger or cylinder are attached; also known as the sling.

Frame size

Commonly used to indicate the size of an electrical drive motor.

Front

The front (of a lift car) is the side in which the entrance is situated or in the case of multiple entrances the side containing the entrance nearest to the car operating panel.

Gear

Wheels working one upon another, by means of teeth (or otherwise) for transmitting or changing motion and power.

Gear, helical

Gear wheels running on parallel axes with the teeth twisted obliquely to the gear wheel axles.

Gear, safety

A mechanical device attached to the car frame or to the counterweight designed to stop and hold the lift car in the event of free fall or of a predetermined overspeed or rope slackening.

Gear, worm

A gear, used to connect non-parallel, non-intersecting shafts, with the teeth of the intersecting wheels cut on an angle.

Generator

An electromechanical device which converts mechanical energy in the form of motion into electrical energy strictly as DC power.

Gib, door

A door component fixed to the bottom edge of a sliding door panel which runs in a machined groove in the sill to guide and correctly hold the door panel in position.

Governor

Strictly a mechanical device which is a closed loop, error activated means of automatically controlling the speed of a machine, but in the lift context it is used to detect an overspeed situation.

Governor, bail-type

A horizontal shaft-type governor.

Governor, centrifugal

A mechanical device which utilises the effects of centrifugal forces operating on weights rotating in a horizontal or vertical plane to provide a movement which can in turn be used to operate a control device.

Governor, displacement-type

Horizontal shaft, centrifugal-type governor, which uses the movement of weights mounted on the governor sheave to operate the rope gripping device.

Governor, flyball

Vertical shaft centrifugal-type governor, which utilises the movement of a pair of flyballs, driven by the vertical shaft, to lift a collar or sleeve, which in turn operates the rope gripping device.

Governor, horizontal shaft

Governor where the activating shaft rotates in the horizontal plane.

Governor, overspeed

A governor used to detect the occurrence of a predetermined speed.

Governor, pull through

Governors of any type, where the rope is gripped by spring-loaded jaws and can 'pull through' rather than being solidly locked to the jaws, thus preventing damage to the rope.

Governor, vertical shaft

Governor where the activating shaft rotates in the vertical plane.

Groove

A long narrow channel machined into a surface.

Groove, U-profile

A groove cut into a drive sheave, which is semi-circular in shape, and of a radius which is approximately equal to the diameter of the suspension rope.

Groove, undercut

A groove cut into a drive sheave, which is a modified V-groove having the lower sides cut in the shape of a 'U'.

Groove, V-profile

A groove cut into a drive sheave in the shape of a 'V'.

Group

A group of cars is a number of cars placed physically together, using a common signalling system and under the control of a supervisory control system.

Guard, counterweight

Unperforated metal guards installed, whenever necessary, in the pit, on all open sides of a counterweight runway.

Guard, sheave

A protective guard around a rope-carrying sheave.

Guard, sight

A vertical strip of material, which is mounted adjacent to the leading edge of a side-sliding landing door and used to block out any view of the hoistway space, whenever the lift doors are in the open position.

Guard, sill

A smooth, often bevelled, apron extending downwards from the sill of the landing or car entrance, with the intention of removing shear hazards to passengers from structural members projecting into the hoistway; also known as the toe guard.

Guide rail

A set of vertical, machined surfaces installed in the hoistway to guide the travel of a lift car or counterweight.

Guide rail, car

Guide rails used to direct the travel of a lift car in a hoistway.

Guide rail, counterweight

Guide rails used to direct the travel of a counterweight in a hoistway.

Guide rail, door

Vertical tracks used to guide the travel of bi-parting freight doors.

Guide shoes

Devices used to guide the movement of doors, cars and counterweights along their associated guide rails.

Guide shoes, door

Guiding devices mounted on both horizontally and vertically moving doors to guide their travel.

Guide shoes, roller

Guide shoes used to guide a lift car or counterweight which are constructed of a set of rollers (three or six) which run on the machined surfaces of the guide rails.

Guide shoes, slipper

Guide shoes used to guide a lift car or counterweight, which are U-shaped so that the gibs surround and bear onto the machined surfaces of the tongue section of the guide rails.

Hall

Synonymous with floor, e.g. floor call, landing; landing pushbutton; corridor; corridor call.

Hall lantern and gong

Unit mounted adjacent to each lift providing a visual and acoustic indication of the availability of a lift car to accept passengers for a specific direction of travel.

Hallway

The lobby or entrance passage to a building and other floors; a corridor or passage.

Handwinding

The action of using a manual lowering device to permit the emergency lowering of a lift.

Hanger, door

An assembly, which is fastened to the top of a door panel, supporting and permitting the sliding movement of the door panel(s), comprising the hanger sheave and hanger track.

Harmonic currents

Alternating currents at multiples of the mains frequency, which flow when a non-linear load is connected to the supply.

Hatchway

Obsolete term used to describe the lift hoistway; derived from the use of a framed and covered opening in a floor.

Header, door

A horizontal structural member located on the hoistway side of a lift entrance used to support the door hanger.

Headroom

Clear working space provided above machinery.

High level language

A term applied to certain computer programming languages to indicate the level of isolation of the user from the underlying computer hardware.

Hoistway

A vertical opening through a building or structure in which lifts, materials lifts, dumb waiters etc. travel. It extends from the pit at the bottom to the underside of the roof or machinery space above.

Hoistway door combination mechanical lock and electrical contact

A device with two functions where the operation of the driving machine is prevented unless the hoistway doors are in the closed position *and* the hoistway doors are locked in the closed position to prevent them being opened from the landing side unless the car is in the landing zone.

Hood

The solid protective screen projecting upwards from the roof of a paternoster car, which continues with the apron of the paternoster car above, to form a continuous cover over the space between cars.

Hydraulic power unit

Part of the lift drive system and comprising pump, pump motor, control valves and fluid storage tank.

Inching

A manual operation, usually carried out on freight lifts, where a car switch or a pushbutton is used to cause the car platform to move in small increments until it is level with the landing sill.

Indicator, call accepted

An indicator adjacent to or contained within a landing call or car call pushbutton, which is illuminated when the lift supervisory control system has accepted the call into its memory.

Indicator, car coming

An indicator adjacent to or contained within a landing call pushbutton, fitted on installations which are controlled by very simple supervisory control systems, and which is illuminated whenever the lift car is coming to the calling landing.

Indicator, car position

An indicator adjacent to or above a car or landing entrance, which is illuminated to indicate the position of the lift car in the hoistway.

Indicator, excess load

An indicator located on the car operating panel, which is illuminated whenever the passenger load in the car exceeds the rated value.

Indicator, landing direction

An indicator adjacent to or above a car entrance, which is illuminated whenever that car is to stop at that landing and which indicates the intended direction of travel for the car.

Indicator, lift in use

An indicator adjacent to or contained within a landing call pushbutton, which is illuminated whenever the lift is busy serving a demand, usually fitted on installations controlled by a very simple supervisory control system.

Indicator, next car

An indicator adjacent to a car entrance or installed inside a lift car, which illuminates to indicate the next car, in a sequence, to leave a specific floor.

Indicator, overload

An indicator, usually installed inside a lift car, which indicates by an acoustic alarm together with an illuminated sign, that the passenger load in the car is in excess of the rated value.

Interference, electrical

Unwanted signals transmitted via the electrical supplies or as electromagnetic radiation, which can interact with properly generated signal sequences to produce incorrect or hazardous operation of equipment.

Interfloor distance

The vertical distance between two adjacent landing floors.

Interlock, car door

A device which prevents the operation of the driving machine unless the hoistway doors are closed.

Interlock, door

A device fitted to a car or hoistway door, usually a mechanically operated electrical contact, which prevents the operation of the driving machine unless certain conditions are satisfied.

Interlock, hoistway door

A device having two functions, where the operation of the driving machine is prevented unless the hoistway doors are in the closed position *and* the hoistway doors are locked in the closed position and prevented from being opened unless the lift car is within the landing zone.

Interval

The average time between successive car arrivals at the main terminal (or other defined) floor with no specified level of car loading or traffic condition.

Interval, down-peak

The average time between successive car arrivals at the main terminal (or other defined) floor with no specified level of car loading during a down-peak traffic condition.

Interval, loading

The minimum time a lift car is held at the main terminal (or other defined) floor, under the up-peak traffic condition, after the first passenger has registered a call, before it is allowed to depart.

Interval, up-peak

The average time between successive car arrivals at the main (or other defined) floor with cars assumed to be loaded to 80% of contract capacity during the up-peak traffic condition.

Interval, waiting

A term sometimes used to designate the up-peak interval and at other times to designate the time a passenger waits for service.

Inverter

A device or circuit for the conversion of direct current to alternating current.

Isolation, car

Means of isolating the passenger cabin from vibration and noise.

Jack

The piston (plunger) and cylinder of a hydraulic lift.

Jamb

The two vertical side posts of a lift entrance, strike jamb and return jamb, plus the lintel or head jamb.

Jamb, head

The horizontal member of the three members constituting a lift entrance, which connects to the side vertical members.

Jamb, return

A vertical member of the three members constituting a lift entrance, behind which the sliding portion of the door passes, whenever it opens and closes.

Jamb, strike

A vertical member of the three members constituting a lift entrance, against which a side-sliding door closes.

Jaws

Parts of overspeed safety gear, which grip the governor rope (in the case of an overspeed governor) and grip the machined surfaces of the guide rails (in the case of car or counterweight safeties).

Jerk

The rate of change of acceleration with time, usually not exceeding 2.2 m/s^3 for lift systems.

Jewel

A coloured or translucent lens or protective cover, which is placed in front of a signal indicator.

Landing

A portion of floor or corridor adjacent to lift car entrances, where passengers may disembark or embark.

Lay

The twisting of yarn (wires) to form a strand or the twisting of strands to form a rope.

Lay, equal

The wires in the strand are so spun that they all have an equal lay length.

Lay, Lang's

The direction of the lay of the wires in the strand is the same as the direction of the lay of the strands in the rope.

Lay, left

The strands of a rope are spun in an anticlockwise direction.

Lay, ordinary

The direction of the lay of the wires in the strand is opposite to the direction of the lay of the strands in the rope.

Lay, right

The strands of a rope are spun in a clockwise direction.

Levelling

An operation which improves the accuracy of stopping at a landing, and which ensures that the car platform is level with the floor.

Lift

A permanent piece of lifting equipment, serving two or more landing levels, provided with a car or platform for the transportation of passengers and/or freight, running at least partially in rigid guides either vertical or inclined to the vertical by less than 15°; known in the USA as an elevator.

Lift, bed

Lifts for the conveyance of patients being moved on beds or stretchers in hospitals, clinics, nursing homes, etc. with a platform shape which is narrow and deep, capable of carrying a load of 20 persons or more and equipped with solid doors of a width of at least 1300 mm and capable of excellent levelling accuracy.

Lift, direct-plunger hydraulic

A hydraulic lift having a plunger or cylinder directly attached to the platform or car frame.

Lift, double deck

A lift having two compartments located one above the other.

Lift, electric

A power lift, which uses an electrical drive machine to provide energy for the movement of the car.

Lift, electro-hydraulic

A direct plunger machine, where liquid is pumped directly under pressure into the cylinder by a pump driven by an electric motor.

Lift, firefighting

A lift, which may or may not be supplied with additional fire resistant protection, designated to have controls that enable it to be used under the direct control of the fire-fighting services for emergency purposes.

Lift, goods (freight)

A lift primarily used to transport freight and goods, where only the operator and persons necessary to load and unload the freight are permitted to travel.

Lift, hydraulic

A power lift, which uses the energy stored in a liquid under pressure to provide the energy for the movement of the car.

Lift, inclined

A lift which travels at an inclination to the vertical of 15° or more.

Lift, maintained-pressure hydraulic

A direct plunger lift where liquid under pressure is available for application to the cylinder at all times.

Lift management

The management of lift systems to provide in-service indication, equipment diagnosis, traffic monitoring and supervisory controller optimisation.

Lift, multi-deck

A lift having two or more compartments located above each other to form a multi-level stack.

Lift, observation

A lift designed as an architectural feature to give passengers a panoramic view while travelling in a partially enclosed well.

Lift, passenger

A lift primarily used to carry passengers other than the operator (if any).

Lift, passenger/goods

A lift of such dimensions that only goods and restricted classes of passengers (such as freight handlers, employees) may be carried.

Lift, roped-hydraulic

A hydraulic lift where the piston is connected to the car by means of wire ropes.

Lift, service

A passenger lift used to transport materials, which conforms to the standards for passenger conveyance, but is often specially strengthened to carry freight or goods.

Lift, wheelchair

A platform lift, which can be fitted to a stairway for the transportation of wheelchairs and which generally can be folded away when not in use.

Lighting, emergency

Lighting provided in a lift car in the event the car becomes stationary between floors and supplied from a standby generator or emergency batteries.

Limit, door close

A contact mounted on the door operator, which is actuated when the doors are fully closed and reduces or removes the power from the door operator.

Limit, door open

A contact mounted on the door operator, which is actuated when the doors are fully opened and reduces or removes the power from the door operator.

Liner, borehole

A rigid capped tube inserted into the borehole of a hydraulic lift to prevent its collapse or the ingress of water.

Liner, guide shoe

The replaceable part of a sliding guide shoe, sometimes called a gib, which slides against the guide rails and steadies the car in its travel.

Liner, hydraulic

An insert placed inside the original cylinder of a hydraulic jack to stop leaks.

Lining, brake

The lining of the brake shoes of a lift made of material possessing a high coefficient of friction.

Linkage, door

Connecting links controlling the motion of the doors and associated with the door operator or the door closer.

Lintel

The horizontal member of an entrance frame used to support the load above the entrance.

Load

The weight of passengers inside a lift car.

Load, average

The weight of passengers carried in a lift car averaged over the number of trips made in a five-minute period.

Load, contract

The weight of passengers which the lift car is certified to carry.

Load, percentage

The weight of passengers carried in a lift car expressed as a percentage of the contract capacity.

Load weighing

Process of determining the number of passengers in a lift car by weighing the load of the car and passengers.

Lobby

An entrance or corridor used as a waiting place; also known as main terminal (floor), foyer, ground (in UK), first (in USA).

Lobby, sky

A terminal floor at the highest floor served by a low zone group of lifts, where passengers may wait for service by a high-rise group of lifts.

Lock, bar

A form of door lock used on manually operated doors.

Lock, door

A mechanical lock of any type which is used to prevent the opening of a car or hoistway door, unless the car is in the door zone.

Machine, basement drive

Where the lift drive machine is located at the bottom of the lift hoistway.

Machine, belt drive

An indirect drive machine using a belt as the means of connection.

Machine, chain drive

An indirect drive machine using a chain as the means of connection.

Machine, direct drive

An electric driving machine where the motor is directly connected mechanically to the driving sheave, drum or shaft with or without intermediate mechanical gearing.

Machine, direct plunger driving

A hydraulic driving machine, where the cylinder is directly connected to the car.

Machine, driving

The power unit which provides the energy necessary to raise and lower a lift, material lift or dumb waiter comprising some or all of the following: electric motor or hydraulic motor; mechanical gearing; brake; sheave, drum or chain sprockets; couplings, shafts, journals and bearings; machine frame.

Machine, (winding) drum

A geared drive machine, where the suspension ropes are fastened to a winding drum.

Machine, electric drive

A driving machine where the energy is supplied by an electric motor.

Machine, geared traction drive

A traction drive machine utilising a gear for energy transmission.

Machine, gearless traction drive

A traction drive machine with no intermediate gearing.

Machine, hydraulic drive

A driving machine where the energy is supplied by the stored energy in a hydraulic fluid applied by means of a moving ram in a cylinder.

Machine, indirect drive

An electric driving machine, where the motor is connected indirectly by means of belts, chains etc. to the sheave, shaft or gearing.

Machine, overhead

Where the lift drive machine is located at the top of the lift hoistway.

Machine, rack and pinion drive

An electric drive machine, where the movement of the car is achieved by power-driven pinions mounted on the car travelling on a stationary rack fixed in the hoistway.

Machine room

A room or space in which the machine(s) and associated equipment are located.

Machine, roped hydraulic drive

A hydraulic driving machine where the cylinder is connected to the car by roping.

Machine, screw

An electric driving machine where the motor drives a screw assembly to raise and lower the car.

Machine, traction

A direct drive machine, where the motion of the car is obtained through friction between the suspension ropes and the driving sheave.

Machine, worm geared

A direct drive machine where the energy is transmitted to the sheave or drum via worm gearing.

Magnet, brake

A solenoid which, when energised, causes the brake shoes to move away from the brake drum.

Maintenance

The action of preservation without impairment of performance.

Maintenance, breakdown

Maintenance undertaken in order that components and equipment may be returned to satisfactory operation.

Maintenance, comprehensive

A form of lift maintenance contract, where the system is inspected, oiled and greased, adjusted and breakdowns repaired during normal working hours, but excluding call backs outside normal working hours, repairs due to vandalism and work arising from legislation.

Maintenance, performance guaranteed

A contract offered to a lift owner, which guarantees certain performance, (for example, number of lifts simultaneously in service, high mean time between failures (MTBF), low periods of down time) and on the failure to perform results, in the lowering of the premium paid to the maintainer.

Maintenance, planned

Preventative maintenance scheduled to be performed at specified intervals of time or for specified numbers of operations.

Maintenance, preventative

Maintenance provided to ensure the satisfactory operation of components and equipment by delaying or preventing or reducing the severity of any breakdown that may occur.

Maintenance, replacement

The replacement of components and materials, which have worn out or reached the end of their useful life.

Mean time between failures (MTBF)

A statistical measure of the reliability of a device or equipment.

Modernisation

The process of improving an existing system by bringing it 'up to date'.

Monitoring, remote

The signalling over a distance of the events (faults, passenger activity, lift activity, etc.) occurring in a lift installation.

Motor

A device which can convert electrical energy into mechanical energy.

Motor generator set

A device comprising an AC motor driving a DC generator and therefore capable of converting one form of electrical energy to another using a mechanical coupling.

Noise, acoustic

Noise which is transmitted through air and which may be generated by parts of a lift installation, such as the machine, car movement, ropes and chains in the hoistway, and transmitted via parts of the structure to remote parts of a building.

Noise, electrical

Noise generated in power devices such as motor generator sets, thyristor (SCR) controllers, etc. and which is transmitted by electromagnetic radiation.

Nosing

Rounded edge of a step or cover for the edge of a step.

Nudging

With automatic door operation, should the doors remain open for longer than a specified time then the doors are compulsorily closed at reduced speed, with the intention of removing any obstruction.

Opening, door pre-opening

The initiation of the door opening sequence, whenever the lift car is within the door zone, in order to reduce the floor-to-floor cycle time.

Operator

Person who rides in the lift car and controls the movement of the car and the opening and closing of the doors.

Operator, door

A power-operated device which opens and closes the hoistway and/or the car doors, where the power is not derived from springs, car movement or manual means.

Overhead

The upper end of the hoistway.

Overhead beam

The steelwork and reinforced concrete located at the top of the lift well, which supports the lift equipment.

Overlay, modernisation

Where a new control system is installed over the top of the existing control system and which takes over the function of the original controller.

Overload

A condition where the rated capacity of a piece of equipment has been exceeded.

Overtravel

The safe distance at which a moving object may travel past its normal point of movement, without hitting any fixed objects.

Pads, sound isolating

Pads made of a dense resilient material, which can be inserted between noise and/or vibration-producing equipment such as a machine, control cabinet or electrical transformer and their fastenings with the building structure, to reduce the intensity of the noise transmitted into a building structure and the air.

Panel, car operating

An assembly of pushbuttons and indicators mounted on a panel inside a lift car including, amongst other things, car call, door open/close, alarm and mechanics control pushbuttons; car call, position, direction and information indicators, together with a number of key-operated switches for use by authorised persons.

Panel, despatcher

Combined starters' and building supervisors' panel comprising, amongst other things, indication of up/down car and landing calls, car position, direction and status together with a number of key-operated switches for use by authorised persons.

Panel, vision

Small window located in lift doors fitted with safety glass which permits passengers to see when a car has reached a landing.

Parking

Action of moving a lift car to a specified floor or leaving it at its current floor, whenever the car has no further calls (landing or car) assigned to it for service.

Passenger

Any person transported by a lift car.

Passenger arrival rate

The rate at which passengers arrive for service by a lift system.

Piston

The smooth circular moving part of a hydraulic jack which is forced out of the cylinder by fluid pressure.

Pit

That part of the hoistway or well situated below the lowest landing served by the lift car.

Pit tanking

Means of preventing the ingress of water into the pit area, which is normally situated at the lowest level in a building.

Plate, kick(er)

Plate used at the bottom of doors, cabinets and risers of steps and car enclosures to protect them from shoe marks.

Platform, car

Load bearing floor of the car enclosure.

Plunger

See *piston*.

Population, building

Total population of a building.

Population, floor

Population of a specific floor in a building.

Power factor

The ratio of active power in kW to the total demand on an alternating current supply in kVA.

Pulley

Simple mechanical device consisting of a grooved wheel over which a rope or similar may pass for the purpose of changing the direction of applied power.

Pulley, diverting

An idler pulley used to change the direction of the rope lead where the drive sheave diameter is less than the distance between the pick-up points of the car and counterweight.

Pulley, governor

The pulley, located with the overspeed governor in the machine room around which the governor rope passes.

Pulley, multiplying

A pulley mounted on the car frame or counterweight round which the suspension ropes pass in order to gain a mechanical advantage.

Pulley, overhead

Pulleys used to alter the pick-up points for the car and counterweight where the machine room is positioned other than directly above the hoistway.

Pulley, tension

The pulley, which is part of the governor tension sheave assembly located in the pit, around which the governor rope passes.

Pushbutton

An insulated button which operates electrical contacts when pushed.

Pushbutton, car call

A pushbutton which generates a car call when pushed.

Pushbutton, door close

A pushbutton which, when pushed, causes the car doors to close .

Pushbutton, door open

A pushbutton which, when pushed, causes the car doors to open.

Pushbutton, landing call

A pushbutton which, when pushed, generates a landing call.

Pushbutton, stop

A pushbutton which, when pushed, causes the lift car to stop.

Quadruplex

A group of four cars sharing a common signalling system.

Quality of service

The passengers' perception of the efficiency of a lift installation measured in terms of passenger waiting time.

Quantity of service

The handling capacity of a lift installation.

Queue

An orderly line of persons waiting their turn.

Ram

See *piston*.

Rated load

The maximum safe load, which a lift car is permitted to carry measured in a number of passengers or a specific weight in kilograms or pounds.

Rated speed

The linear car speed in the hoistway, which the lift manufacturer contracts to supply.

Reactor, saturable

A magnetic device for the control of the value of alternating current flowing in a circuit.

Rectifier

A device for the conversion of alternating current to direct current.

Registration, call

Action of the passenger in the registration of a car or landing call.

Relay, phase failure

Relay which detects a failure of a phase of an incoming electrical supply and which causes the lift system to be shut down.

Relay, phase reversal

Relay which detects a phase reversal of an incoming electrical supply and which causes the lift system to be shut down.

Relay, time delay

A relay which acts as a timing device by delaying the application of a control signal.

Re-levelling

After a lift car has stopped level at a floor, an operation permitting the stopping position to be corrected (if necessary) during loading and unloading, by successive car movements.

Return

To take or lead-back at an angle, often 90°, upon a former direction.

Rise

The vertical distance between two steps in a stair.

Riser

The upright part of a step; the vertical piece connecting two treads in a stair.

Riser, electrical

A vertical enclosed space in a building from which electrical distribution is made.

Rope

A construction of twisted fibres or wire (wire rope) to form a continuous load-bearing element.

Rope, compensating

Wire rope used to counterbalance or partially counterbalance the weight of the suspension ropes as the lift car moves up and down the hoistway.

Rope, governor

A wire rope attached to the lift car, which drives the governor.

Rope, safety

Rope attached between the governor rope and the safety gear.

Rope, suspension

The ropes in a lift system used to suspend the car and counterweight in the hoistway.

Rope, wire

Rope made by twisting wires around an inner core.

Roping, one-to-one

An arrangement of ropes, where the mechanical advantage is one and hence the suspension ropes, car and counterweight all travel at the same speed.

Roping, two-to-one (2:1)

An arrangement of ropes, where the mechanical advantage is two and hence the rope speed is twice that of the car and counterweight.

Run-by

The unobstructed distance a car or counterweight may travel at the extremes of the hoistway before an obstruction is encountered.

Run-by, bottom — lift car

The distance between the car buffer striker-plate and the car buffer striking-surface, when the lift car floor is level with the bottom landing.

Run-by, bottom — counterweight

The distance between the counterweight buffer striker-plate and the counterweight buffer striking-surface, when the car is level with the highest landing.

Run-by, top — direct-plunger hydraulic lift

The distance the lift car can run above the highest terminal landing, before it strikes the mechanical stop.

Safe-edge

A mechanically actuated door re-opening device mounted on the leading edge of a car door which on colliding with a passenger or other object causes the car and landing doors to re-open.

Safety

A generic term used to describe the safety features employed in lift installations.

Safety, car

Mechanical device attached to the car frame to stop and hold the car should any of three conditions occur: free fall, predetermined overspeed or rope slackening.

Safety, counterweight

Mechanical device attached to the counterweight frame to stop and hold the counterweight should any of three conditions occur: free fall, predetermined overspeed or rope slackening.

Safety, flexible guide clamp

A form of car safety where a pair of wedge-shaped jaws are actuated under unsafe conditions and grip the guide rails to bring the car to a safe stop.

Safety gear

Mechanical devices used to stop a car or counterweight under specific conditions.

Safety gear, instantaneous

A form of safety gear which applies a rapidly increasing pressure on the guide rails during the stopping period.

Safety gear, instantaneous with buffered effect

A form of safety gear which applies a rapidly increasing pressure on the guide rails during the stopping period but with a buffered effect provided by oil buffers interposed between the lower members of the car frame and the safety plank.

Safety gear, progressive

A form of safety gear which applies a limited pressure on the guide rails during the stopping period.

Safety plank

Bottom member of the car frame supporting the car guide shoes and safety gear.

Sector

A group of landings or landing calls considered together for lift car allocation or parking purposes.

Sector, common

Static sector defined for both up and down landing calls originating from a number of contiguous landings.

Sector, directional

Static sector that includes a number of contiguous landings defined for one landing call direction only.

Sector, dynamic

Sector whose boundaries are defined by the position of the cars and hence are continually changing.

Sector, static

Fixed number of landings grouped together.

Selector, floor

Part of the control system of some lifts which determines the position of the car in the hoistway and automatically stops it at the required landing.

Service, basement

The provision of passenger service to the basement or basements of buildings on a special or regular basis.

Service, firefighting

A lift which serves all floors in a building and which can come under the sole command of a fireman in the event of a fire in the building.

Service, independent

Operation of a lift so that it only answers car calls, and which is brought into operation by the use of a special key switch located in the car.

Service, intensive duty

Where a lift system makes 180 or more starts per hour.

Service, light duty

Where a lift system makes 90 or less starts per hour.

Service, medium duty

Where a lift system makes from 90 to 180 starts per hour.

Sheave

A wheel having a groove or grooves in its circumference, in order to receive a rope or ropes; a pulley.

Sheave, chain

Sheave with rectangular shaped groove over which a chain may run.

Sheave, compensating rope

A pit-mounted grooved sheave which guides and maintains the tension on the compensating ropes.

Sheave, deflector

Grooved sheave used to deflect ropes in order to place them in the correct lifting positions.

Sheave, door hanger

Small grooved sheave which runs on the door track and which allows the door to slide easily.

Sheave, drive

A wheel, the rim of which is grooved to receive the suspension ropes, and which allows the motion of the driving machine to be transmitted to the ropes by friction.

Sheave, idler

Grooved sheave used to guide, to change direction or to apply tension to a rope.

Sheave, secondary

A groove used to permit the double wrapping of the suspension ropes in order to increase traction.

Sheave, tension

A sheave used to maintain tension on a rope.

Sheave, governor tension rope

A weighted, pit-mounted sheave used to maintain tension on a governor control rope.

Shim, kicker

Small slotted plate used to pack out, align or square-up guide rails.

Shoes, brake

The moving member of a brake which is lined with a high coefficient of friction material such that when operated against the brake drum the lift car can be held in a stationary position or brought to rest.

Shoes, roller guide

Component used to guide a lift car or counterweight along the guide rails comprising a set of three (or six) spring-loaded rubber-tyred rollers.

Shoes, slipper guide

Component used to guide a lift car or counterweight along the guide rails comprising a set of swivel shoes lined with a low coefficient of friction material running against greased guide rails.

Sill (cill)

Lower horizontal part of a doorway.

Sill, door

Lower horizontal member of a landing entrance.

Sill-stop

Support member fastened to the guide rails of vertical bi-parting doors.

Simulation

The development and use of models to aid in the evaluation of ideas and the study of dynamic systems or situations.

Single automatic pushbutton

An automatic pushbutton control system, where only one button is provided on the landing to indicate both directions of travel.

Single wrap

Roping arrangement, where one end of the suspension rope is fastened to the car, passes over the drive sheave and is then fastened to the counterweight.

Skip-stop operation

Where a duplex pair of lifts in a building share a common lobby but one car serves even floors and the other serves odd floors.

Skirting (board)

Narrow boarding placed at the base of a wall.

Sling

Device for hoisting bulky or heavy articles.

Socketing

The preparation of suspension rope end fastenings.

Soffit

The horizontal under-surface of an architrave, cornice, lintel or arch.

Solid state

Electronic circuits making use of semi-conductor physics.

Speed, rated (contract)

The linear car speed in the hoistway, which the lift contractor contracts to supply.

Spring, buffer return

Spring used to return an energy dissipation type of buffer back to its operating position.

Stair climber

A form of stair-climbing lift on which a person with impaired mobility can sit in order to reach another floor.

Standard

An authoritative or recognised exemplar of correctness, perfection, or some definite degree of any quality.

Station, car-top inspection

Control panel situated on the top of the car which allows the lift to be removed from service and controlled from the car top.

Status

An event which is not a failure or an error, but which provides information about the operation or status of a lift system.

Stile

Vertical member of the car frame.

Stop, car

A stop by a lift car at a floor resulting from a car call.

Stop, down

A stop by a lift car whilst travelling in the down direction.

Stop, landing call

A stop by a lift car resulting from a landing call.

Stops, probable

The average number of stops a lift car makes, during a round trip under up-peak traffic conditions, calculated using statistical methods.

Stop, up

A stop by a lift car whilst travelling in the up direction.

Stroke, oil buffer

Distance the buffer piston or plunger moves, excluding the travel of the buffer plunger accelerating device.

Stroke, spring buffer

Distance the contact end of the spring moves, before all the coils are in contact or a fixed stop is reached.

Switch, buffer

A mechanically operated switch, which removes power from the drive system, whenever the oil buffer is compressed.

Switch, car

An attendant-operated switch mounted in the car used to control the motion (starting and stopping) of the car.

Switch, displacement

Switch actuated by the displacement of the counterweight used to signal to the control system that a collision is possible.

Switch, door

Switch operated by the movement of a door.

Switch, door limit

Switch which limits the travel of a door.

Switch, emergency stop

Switch located in the lift car which when operated causes the power to be removed from drive machine and brake.

Switch, final limit

Emergency switch used to stop a lift automatically, in the event that the car travels a predetermined distance past the terminal landing.

Switch, final terminal stopping

A mechanically operated switch, which automatically causes the power to be removed from the drive machine and brake, independent of the normal terminal stopping switch, car switch, pushbutton or any other control device.

Switch, firefighting

Switch which when operated brings the designated car under the control of the firefighting service.

Switch, floor stopping

Switch or switches used to bring a car to rest at or near a designated floor.

Switch, governor overspeed

Mechanically operated switch located on the governor, which removes the power from the drive machine and brake, whenever an overspeed condition occurs.

Switch, key

Switch which can only be operated by means of a key.

Switch, limit

Switch placed in the hoistway to indicate to the control system that a specified limit has been passed.

Switch, normal terminal stopping

Switch of any type which causes the lift automatically to slow down and stop at or near the terminal landing, independent of the car switch, pushbutton or any other control device.

Switch, oil buffer

Switch used to indicate that the level of oil in an oil buffer has fallen below a specified level and to prevent operation of the lift.

Switch, pit

Emergency stop switch located in the pit, which when operated causes power to be removed from the drive machine and brake.

Switch, service

Key-operated switch which is not operative whilst the car is in motion, used to take the lift out of service.

Switch, slack rope

Switch or switches arranged to stop the lift should the suspension ropes slacken by a predetermined amount.

Switch, slow down

Hoistway-mounted switch used to control the slow down sequence of a car to a landing.

Switch, stopping

Switch actuated by the movement of the car, at predetermined points in the hoistway, and which causes power to be removed from the drive machine.

Switch, terminal slow down

A limit switch located at a terminal landing, which initiates a slow down sequence in the event the normal slow down system fails to function.

System, signalling

Means of indicating landing calls to the supervisory control system using a common riser of landing pushbuttons.

Tape, steel

Tape, usually toothed, used to drive tachometers, position sensors and governors.

Test, acceptance

Inspection and test of new or altered equipment to check for with code/standard compliance and contract conformance.

Test, periodic

Detailed examination and tests carried out periodically to ensure continued compliance with relevant codes and standards.

Test, safety

Procedure whereby all parts of the lift car safety gear and governor are subjected to a rigorous visual inspection and then tested under controlled operating conditions.

Thyristor

A three-terminal semiconductor rectifier which can be controlled to turn on at any point during the positive half cycle of the AC waveform.

Time

The interval between two successive events or the period through which an action, condition, or state continues.

Time, boarding

See *time, passenger loading*.

Time, cycle

The time for a lift to move from one floor to the next adjacent floor, measured from the instant that the doors start to close at the departure floor to the instant the doors start to close at the arrival floor, provided that no passengers have entered or left the car.

Time, dispatch interval

The period of time between successive car departures from a terminal floor for a group of lifts controlled by a scheduling supervisory control system.

Time, door closed

The period of time which lift doors remain closed.

Time, door closing

The period of time measured from the instant that the door close pushbutton is pressed (or the first visible door movement) until the door interlocks are made up.

Time, door dwell

The time that the lift doors are held open at a landing, after the door opening sequence has been completed.

Time, door hold(ing)

See *time, door dwell.*

Time, door open

The period of time that the lift doors remain open.

Time, door opening

The period of time measured from the instant of the lift car being level at a floor and when the doors are 90% open.

Time, flight

See *time, single-floor flight* and *time, multiple-floor flight.*

Time, floor-to-floor

See time, single-floor flight or multiple-floor flight.

Time, interfloor

The period of time for a lift car travelling at contract speed to pass between two adjacent floors.

Time, loading interval

The period of time that a car may be held at the main terminal after the first passenger has registered a car call.

Time, multiple-floor flight

The period of time measured from the instant when the door interlocks are made up at the departure floor until the instant that the lift car is level at the next stopping floor, which can be more than two floors distant.

Time, passenger journey

The period of time that a passenger spends travelling to a destination floor measured from the instant that the passenger registers a landing call at the departure floor until the instant the passenger alights at the destination floor.

Time, passenger loading

The average period of time required for a single passenger to enter a lift car.

Time, passenger transfer

The average period of time required for a single passenger to enter or leave a lift car.

Time, passenger unloading

The average period of time required for a single passenger to leave a lift car.

Time, passenger waiting

The period of time that a passenger spends waiting for a lift car measured from the instant that the passenger registers a landing call until the instant the passenger enters the car.

Time, round trip

The average period of time for a single lift car trip, usually during up-peak traffic conditions, measured from the time the car doors open at the main terminal until the car doors reopen at the main terminal, on completion of the round trip.

Time, running

The total period of time, during a round trip, when the lift is moving.

Time, single-floor flight

The period of time measured from the instant when the door interlocks are made up at the departure floor until the instant that the lift car is level at the next adjacent landing.

Time, standing

The total period of time, during a round trip, when the lift is not moving.

Time, stop

A composite time period which represents the 'penalty' time introduced by the lift car stopping at a floor and which comprises the sum of door opening, door closing and single floor flight times minus the transit time to pass between two floors at contract speed (interfloor time).

Time, system response

The period of time that it takes a lift group to respond to the first registered landing call at a floor.

Time, transit

The period of time that a passenger spends travelling in a lift car measured from the instant that the passenger boards the car until the instant that the passenger alights at the destination floor.

Track, door

A rail on which the door hanger rolls and which allows the horizontal sliding movement of the doors.

Track, door hanger

An assembly fastened to the top of a door panel which allows the horizontal sliding movement of the door.

Traffic analysis

Determination of the statistical characteristics of passenger movements (average passenger waiting and journey times, percentiles, etc.) in a lift system.

Traffic, down-peak

A down-peak traffic condition exists when the dominant or only traffic flow is in a downward direction with all or the majority of passengers leaving the lift system at the main terminal of the building.

Traffic, (balanced) interfloor

A traffic condition where there is no discernable pattern of calls and a random traffic pattern can be said to exist.

Traffic, intensive

Where an individual lift car is expected to undertake more than 180 starts per hour.

Traffic, light

Where an individual lift car is expected to undertake 90 or less starts per hour.

Traffic, medium

Where an individual lift car is expected to undertake between 90 and 180 starts per hour.

Traffic, two-way

A two-way traffic condition exists when the dominant traffic flow is to and from one specific floor, which is not the main floor.

Traffic, up-peak

An up-peak traffic condition exists when the dominant or only traffic flow is in the upward direction with all or the majority of the passengers entering the lift system at the main floor of the building.

Transportation, horizontal

Where the movement of people and materials is in the horizontal plane.

Transportation, vertical

Where the movement of people and materials is in the vertical plane.

Travel

The vertical distance a lift can move, measured between the bottom terminal floor and the top terminal floor of a building zone.

Trip, express (run)

The distance a lift travels without stopping during a movement between terminal floors or when crossing an unserved building zone.

Triplex

Three interconnected cars, sharing a common signalling system, controlled under a simple group control system operating under directional collective principles.

Tropicalise(d)

The treatment of equipment to allow it to operate reliably without adverse effects in high temperature and/or high humidity conditions.

Valve, bypass

A hydraulic valve which diverts the hydraulic pump output from the fluid power line to the fluid tank.

Vane

A thin piece of metal, positioned in the hoistway, which operates as the actuating part of a magnetically operated switch.

Vane, door

A mechanism mounted on a car door which transmits operating power to the hoistway doors.

Velocity

The rate of change of position with time.

Ventilation, car

Means of removal of heat, generated inside the car, by natural or mechanical means, via suitable vents placed in the car enclosure.

Viscosity

The specific resistance of a fluid to flow at a velocity relative to its surroundings.

Weighing, load

A means of determining the total weight (but not number) of passengers being carried in a lift car.

Well

The space bounded by the bottom of the pit and the walls and roof of the hoistway in which the car and counterweight travel.

Wheel, worm

Part of a worm gear.

Wrap, double

A roping arrangement where, in order to increase the traction, the rope joining the car and the counterweight passes over the drive sheave twice.

Wrap, single (1:1)

A roping arrangement where the rope joining the car and the counterweight passes over the sheave once.

Zone

A number of floors, usually adjacent, in a building served by a group or groups of cars.

Zone, door

A distance (about 30 cm) measured from the landing floor, in both directions, in which it is permitted for the car doors to be opened, when a car is levelling at a floor.

Zone, high-rise

A building zone situated in the middle or top of the building.

Zone, levelling

A distance near to each landing floor in which a lift car slows and 'inches' towards the floor level.

Zone, local

A building zone adjacent to and including the main floor.

Zone, parking

An area designated for the parking of cars when they have served their last car call.

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