History of the Safety Gear

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Abstract. The safety gear is regarded as the last line of defence in the relatively safe world of lifts. Industry contemporaries recall Elisha Otis declaring “All safe” after cutting the ropes on a platform upon which he was standing and the safety gear preventing his uncontrolled descent. The design of safety gears has moved on significantly from an original proposal to place a bag of feathers in the lift pit to designs that now arrest uncontrolled movement in ascent. This paper is a developing research project which will look at UK patents and standards and tracks the development of the safety gear from the embryonic days of lift installations to the present day. It will contribute to knowledge by bringing together a number of sources of information not previously brought together into a single paper and thus provide a consolidated history of the safety gear.

Keywords: Safety gear, Otis, Falling, Standards, EN81, BS2655, BS5655

1 INTRODUCTION

A literature search has revealed limited historical information about safety gears fitted to passenger lifts. Most literature is of a technical or sales nature rather than being in a historical context. Manufacturers of lifts have been taken over by companies over the years and in many cases historical information about a company’s history has been lost. There are a few exceptions, but most information is about the company rather than their products. It is common knowledge that Elisha Graves Otis designed the first safety gear and his paper presented to the Newcomen Society American Branch in New York 1945 gave good insight into the man himself as well as the product. Another author, John Inglis, based in Australia presented a paper at Elevcon in 1998 entitled “Evolution of Safety Gear” which has provided some interesting drawings for this paper however the paper did not look at changes in standards in a chronological way. Other historical books were located including “Electric Lift Equipment for Modern Buildings” (1923) by Grierson and “Electric Lifts” by R S Phillips (1939) “Giving rise to the modern city” by Jason Goodwin (2001) and “A history of the passenger elevator in the 19th century” by Lee Gray (2002). Various books of a technical nature were located however historical and developmental information about safety gears was not covered. The British Standards published since 1970 were reviewed including BS 2655-1 (1970), BS5655-1 (1979) and BS5655-1 (1986) after which the European Norm standards saw the dropping of the BS prefix in favour of EN. These included EN81-1 (1990) **inc** Amendment A3, EN81-20 (2014) and EN81-50 (2014). Manufacturers were also contacted for documentation and information which will be reviewed as and when it is received. The literature review has revealed that there is very little information about the development of the safety gear and finding information is difficult but not impossible. The elimination of the safety gear has been proposed on many occasions which makes this research a piece of legacy work that may become important as a future student can take it forward from the cessation point of the final research such that a chronology from its invention in 1853 can be established. This work can therefore be concluded as being novel and in the educational and public interest.

2 ELISHA OTIS

Otis was born in Halifax, Vermont to Stephen Otis and Phoebe Glynn. He moved away from home at the age of 19, eventually settling in Troy, New York, where he lived for five years employed as a wagon driver. In 1834, he married Susan A. Houghton. They would have two children, Charles and Norton. Later that year, Otis suffered a terrible case of pneumonia which nearly killed him, but he earned enough money to move his wife and three-year-old son to the Vermont Hills on the Green River. He designed and built his own gristmill, but did not earn enough money from it, so he converted it into a sawmill, yet still did not attract customers. Now having a second son, he started building wagons and carriages, at which he was fairly skilled. His wife later died, leaving Otis with two sons, one aged 8 and the other still a young child [10].

Aged 34 and hoping for a fresh start, he married for a second time and moved to Albany, New York. He worked as a doll maker for Otis Tingely. Skilled as a craftsman and tired of working all day to make only twelve toys, he invented and patented a robot turner. It could produce bedsteads four times as fast as could be done manually (about fifty a day). His boss gave him a $500 bonus. Otis then moved into his own business. At his leased building, he started designing a safety brake that could stop trains instantly and an automatic bread baking oven. He was put out of business when the stream he was using for a power supply was diverted by the city of Albany to be used for its fresh water supply. In 1851, having no more use for Albany, he first moved to Bergen City, New Jersey to work as a mechanic, then to Yonkers, New York where he worked as a manager of an abandoned sawmill which he to convert into a bedstead factory.

In his spare time, he designed and experimented with his old designs of bread-baking ovens and train brakes, and patented a steam plough in 1857, a rotary oven in 1858, and, with Charles, the oscillating steam engine in 1860. Otis contracted diphtheria and died on April 8, 1861 at age 49.

When he died he owned a factory worth not more than $5,000, employing only 8 or 10 men[1].

3 THE INVENTION OF THE SAFETY GEAR

“The significant influence of lifts dates from the invention by Elisha Graves Otis of a device capable of keeping a lift from falling even though the hoisting ropes should break”[1]

In 1851 Elisha Graves Otis went to Bergen, New Jersey and then a year later to Yonkers, New York in his employ as master mechanic of the bedstead plants in which his employer, Josiah Maise, was an owner. It was here that he came face to face with his destiny and he designed and installed the first lift equipped with an automatic device to prevent it from falling. [1]

He was destined to move to California, however, an unsolicited order for two safety lifts had been received from a Mr Newhouse, a furniture manufacturer in whose plant at 275 Hudson Street, New York, a serious accident had just occured. The order for these two lifts marked the beginning, in 1853, of the now worldwide association of elevators and the name Otis.[1]

In 1853 an exhibition was held at the Crystal Palace in New York City at which Elisha Graves Otis demonstrated his confidence in his own product by standing on the platform of the lift erected at the exhibition, raising the platform well above the heads of the assembled crowd, and then at the most dramatic point in his oratorical exposition, cut the rope by which the platform was suspended. Those who had morbidly anticipated a leg breaking crash, however disappointed, were nevertheless impressed with the effectiveness of the Otis Safety when, as a matter of fact, nothing happened. [1] It is said that after the descending platform was arrested Elisha Otis uttered the words “All Safe Gentlemen”

Fig 1: Elisha Otis demonstrating his safety gear in 1853

The New York Tribune reported the exhibition and made mention of the Otis invention however it should be noted that they referred to the lift at the exhibition as one for hoisting goods and it was not until three years later that the first passenger lift was manufactured by Otis and installed in a five-story building on the north-east corner of Broome Street and Broadway which belonged to E V Haughwout & Co, dealers in china and glassware. [1]

4 DEVELOPMENT OF SAFETY GEAR DESIGN

According to Inglis[2] the earliest story known about safety of persons whilst travelling in a lift dates back to a Sultan who required a means of lifting people to the upper floor of his castle. It is said that a large bag of feathers was placed in the pit and one of his servants rode in the lift car whilst the rope was cut. The servant apparently survived the fall with only a broken leg and the Sultan therefore concluded that no one would be killed whilst using his lift.

In the early days car guide rails were often timber and a knife action safety gear would embed itself into the timber guides which would have to be replaced after each application. This was obviously an unsatisfactory situation and often rendered a lift out of service for a long period of time whilst replacement guide sections were obtained. This type of safety gear, as with many others, was also plagued by nuisance tripping in the event that the knife blade ran too close to the timber guides or a build-up of detritus caused it to operate.

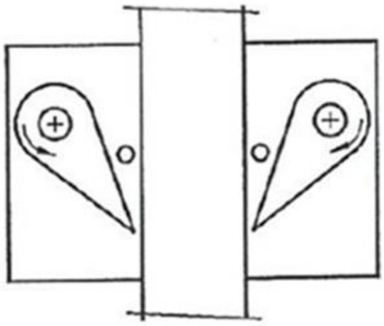


Fig 2: Early design of a safety gear using knives that dug into wooden guides (source: Inglis)

In his paper Inglis goes on to record a further development where an Italian invented a method of preventing injury in the event of free fall or an overspeed condition in the down direction. This is the first located mention of an overspeed condition. The invention consisted of some rods across the car above the passengers' head with the rods terminating in two rubber diaphragms at their ends. In the event of overspeed in the down direction a passenger would hold onto the bar with the diaphragms taking the force out of the impact when the car hit the buffers. There was the obvious question of how many passengers could be protected by such a device.

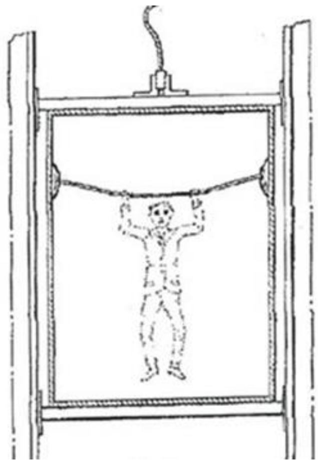


Fig 3: Italian invention with rods above passenger's heads (source: J Inglis)

The development of high speed lifts necessitated the development of a new type of safety. It is elementary that the purpose of a safety device is not merely to stop the lift platform, since this could be done with absolute certainty by simply letting the platform hit the bottom of the hatchway, but rather to bring the platform to a sufficiently gradual stop to prevent injury. The early safety, which contributed so greatly to the fame and fortune of Elisha Graves Otis, was of the instantaneous type which operated only in the event of slack or broken ropes and was useful only because it applied when the lift had barely started to fall and before it had attained a downward speed greatly in excess of the normal speed, which was slow. Obviously, with a high-speed lift it would be almost as disastrous to stop the lift at high speed with a safety of instantaneous type as it would be too hit the bottom, or at any rate the stop would be more sudden than the human body could stand without sustaining an injury. [1]

According to Grierson[3], up to about the year 1880 cast iron racks or ratchets were attached to the guides, and a pair of dogs, fixed at the top of the car attached to the single suspension rope, and operated by springs, formed the safety gear. Note the single rope, a situation no longer permitted for lifts although still seen in mine winding and cable car applications. When the rope failed, the springs that operated the dogs engaged with the racks on the guide posts and immediately brought the car to a dead stop. Grierson also states that "safety gear is not ordinarily fitted to counterbalance weights, only the car."

The next important development, according to Grierson, appeared around 1893 which is still extensively in use in Great Britain today (bear in mind Grierson was published in 1923) was cam type guide grips. It consists of four serrated steel cams, mounted on two turned steel rods, that, when the necessity arises, rotate and bring the cams into contact with the guide rails or wood backing.

This safety gear was only suitable for slow speed cars (100 ft/min) due to it acting almost instantaneously The design would also only protect against a too rapid descent of the lift car and was useless for excessive speed in the upward direction. Grierson noted that various manufacturers used different methods of safety gear activation including slack rope activation and a separate safety line connected between the car and counterweight.

In 1878 an overspeed governor of the fly ball type was invented for the purposes of operating a progressive safety gear. This was invented by Charles R Otis.[1]

5 HISTORY OF THE BRITISH STANDARDS INSTITUTION (BSI)

The history of the British Standards Institution can be found on the BSI website [11]

The chronology shows an interesting start to the standards movement in the UK and the period when other groups were doing the work can be accounted for by looking at this timeline.

According to the website [11] BSI was formed in 1901 by Sir John Wolfe-Barry - the man who designed London’s Tower Bridge - BSI was the world’s first National Standards Body. The original BSI committee met for the first time on the day Queen Victoria died – 22 January 1901. One of the first standards it went on to publish related to steel sections for tramways.

The BSI Kitemark was first registered by BSI on 12 June 1903 – the same year in which Harley Davidson, Crayola crayons and the Tour de France were born. Originally known as the British Standard Mark, it has grown into one of Britain’s most important and most recognized consumer quality marks.

In the years between 1914 and 1945 standardization grew. This is quite interesting as these dates coincide with the start of the first world war and the end of the second world war.

During the 1920s, standardization spread to Canada, Australia, South Africa and New Zealand. Interest was also developing in the USA and Germany.

In 1929 the Engineering Standards Committee was granted a Royal Charter. A supplemental Charter was granted in 1931 changing the name, finally, to The British Standards Institution.

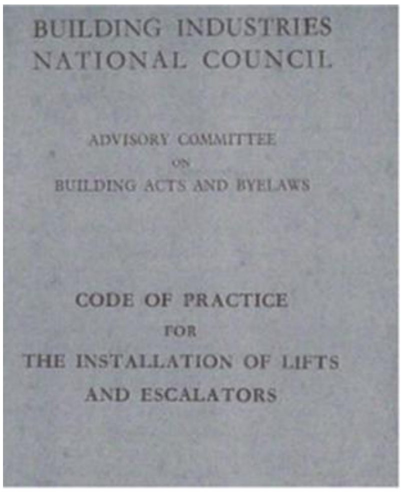
Again, this is significant when you look at the 1935 and 1943 Codes of practice published by the Building Industries National Council (BINC) as in 1931 BSI was a standards organisation in its own right and it would appear the BINC was a competitor.

In 1942 the British Government officially recognized BSI as the sole organization for issuing national standards. Why then did BINC publish a Code of Practice in 1943? The answer may lay in the war years as between 1939 and 1945, during World War II, ordinary standards work was stopped, and efforts were concentrated on producing over 400 ‘war emergency standards'.

At the end of the war in 1945 a BSI Kitemark licence was issued for copper pipe fittings that is still going strong today – it’s the longest running BSI Kitemark.

6 PRE-BRITISH STANDARD CODES OF PRACTICES

6.1 Building Industries National Council, Code of Practice for the Iinstallation of Lifts and Escalators, 1935


BUILDING INDUSTRIES
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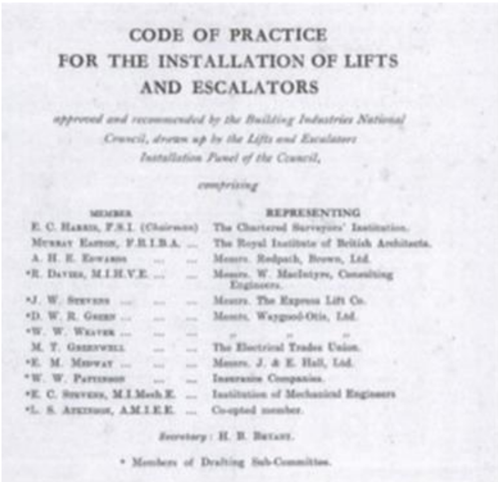
ADVISORY COMMITTEE
ON
BUILDING ACTS AND BYELAWS

CODE OF PRACTICE
FOR
THE INSTALLATION OF LIFTS
AND ESCALATORS

Fig 4 1935 Code of Practice

It is interesting to note who represented various parties on the committee including private companies. There were only 12 people on the committee, but notable lift companies represented were The Express Lift Co (J W Stevens), Waygood Otis (D W R Green and W W Weaver), J & E Hall (E M Medway)


CODE OF PRACTICE
FOR THE INSTALLATION OF LIFTS
AND ESCALATORS

approved and recommended by the Building Industries National Council, drawn up by the Lifts and Escalators Installation Panel of the Council,

comprising

MEMBER	REPRESENTING
E. C. Harris, F.S.I. (Chairman)	The Chartered Surveyors' Institution.
Murray Easton, F.R.I.B.A. ...	The Royal Institute of British Architects.
A. H. E. Edwards	Messrs. Redpath, Brown, Ltd.
*R. Davies, M.I.H.V.E.	Messrs. W. MacIntyre, Consulting Engineers.
*J. W. Stevens	Messrs. The Express Lift Co.
*D. W. R. Green	Messrs. Waygood-Otis, Ltd.
*W. W. Weaver	" " "
M. T. Greenwell	The Electrical Trades Union.
*E. M. Medway	Messrs. J. & E. Hall, Ltd.
*W. W. Pattinson	Insurance Companies.
*E. C. Stevens, M.I.Mech.E. ...	Institution of Mechanical Engineers
*L. S. Atkinson, A.M.I.E.E. ...	Co-opted member.

Secretary: H. B. Bryant.

* Members of Drafting Sub-Committee.

Fig 5 Members of the 1935 panel

The Code of Practice required that:

EMERGENCY SAFETY DEVICES

12(a) Every power-driven lift suspended by wire ropes shall be provided with a car safety gear, attached to the car frame and preferably placed beneath the car. The safety gear shall be capable of stopping and sustaining the car with full contract load in the car.

12(b) Every power-driven lift having a travel exceeding 18' shall be equipped with an overspeed governor device which will operate to apply the safety gear in the event of the speed of the car in the descending direction exceeding a predetermined limit.

12(c) The application of the safety gear shall not cause the car platform to become out of level in excess of ¼" per foot, measured in any direction.

12(d) When the safety gear is applied, no decrease in the tension of the governor rope or motion of the car in the descending direction shall release the safety gear.

12(e) It is permissible to release the safety gear by reversing the direction of motion of the machine.

12(f) The safety gear shall operate to stop and sustain the car in the event of failure of the suspension ropes or in the event of the lift exceeding a predetermined maximum speed in the descending direction when a speed governor is fitted.

12(g) Every safety gear shall operate positively and mechanically, independently of any springs used in its construction.

12(h) Any levers or dogs operated by shafts shall be keyed to such shafts by B.S.S No 46 keys.

12(i) The design of safety gear shall provide for its application to both guides and to each side of the guides equally.

12(j) Any additional rope used solely for the purpose of operating the safety gear must be led over independent pulleys, running on independent shafts.

12(k) All bearings for drums and screw shafts in connection with safety gears must be on non-ferrous metals.

12(l) The car speed governor shall be set the cause the application of the safety gear at a speed of not more than 40 per cent., and not less than 15 per cent., above the contract speed provided that no governor shall be required to trip at a speed less than 175 feet per minute and with instantaneous type of safety gear shall trip at a speed not exceeding 250 feet per minute.

12(m) The counterweight safety gear, if provided, may be operated by the same governor and governor rope to operate the car safety gear provided it complies with the requirements for, and for the application of, counterweight safety gears. Provision shall be made to cause the application of the counterweight safety gear at a speed greater than the car safety gear, but at not more than 10 per cent in excess of that at which the car safety gear applies.

12(n) Broken rope safety gears of the instantaneous type may be used on counterweights within the following limits:

Contract Speed (ft per min)	**Total weight of counterweight in pounds**
250	2,000
200	3,000
150	4,000
100	5,000

12(o) Three types of safety gear are recognised at present, viz:

i. Instantaneous type, Limited to speeds not exceeding 200 ft per minute (Type I)

ii. Gradual Wedge Clamp Type, with gradual increasing retarding force (Type G.W.C)

iii. Flexible Guide Clamp Type, with constant retarding force. (Type F.G.C)

12(p) No safety gear shall be permitted to stop an ascending car or counterweight. If an ascending car is to be stopped on account of overspeed, a safety gear shall be fitted to the counterweight for this purpose. The governor may, however, open the motor circuit and apply the brake in the event off overspeed in the ascending direction.

12(q) The governor must be placed where it cannot be struck by the car in case of overtravel and where there is sufficient space for the full movement of the governor parts.

12 (r) The motor control circuit and the brake control circuit shall be opened before or at the same time as the governor trips.

12(s) Governor ropes shall run clear of the governor jaws during the normal operation of the lift.

12(t) The proper tripping speed of the governor shall be stamped on the governor base or on a brass plate attached to the base.

12(u) When replacing governor ropes, they shall be of the same size, material and capacity as the ropes supplied originally and installed by the makers of the lift, except that where a rope of different characteristics is proposed, a test of the car and/or counterweight safety gear shall be made, to determine the fitness of the new ropes.

12(v) The ~~are~~ (area) of contact between the governor jaws shall be such that no serious cutting, tearing or deformation of the rope shall result for the operation of the safety gear.

12(w) It is recommended that governor gears have self-lubricating bearings which do not require frequent attention.

12(x) In the case of a safety gear actuated by means of a rope unwinding from a drum, such drum shall have at least three complete turns on the drum after the safety gear has been applied and the car stopped. The minimum diameter of such drum shall be 5" (Five inches). The device for holding the safety rope or rod in position during normal operation shall be fixed to the steel framework of the car and not to the car bodywork. The ends of the governor rope shall be held by a clevis or other similar means, which shall effect its purpose by friction. The clevis or other holding device shall be supported by or from the steel framework of the car and not fixed to the car bodywork.

12(y) No safety gear shall depend on the completion or maintenance of an electric circuit for its operation. All safety ears shall be applied mechanically.

12(z) The gripping surfaces of car or counterweight safety gears shall not be used to guide the car or counterweight, but shall run free of the guides during normal operation of the lift.

Note: A pawl or ratchet shall not be held a sufficient safety gear for lifts travelling in a vertical or substantially vertical direction.

This standard also went on to describe safety gear testing in section 13 as follows:

13(a) A contract load test shall be made by the lift maker of the safety gear or gears of each new lift, before such lift is put into service for normal and regular operation. This test shall be made to determine whether the safety gear will operate satisfactorily within the specified limits.

13(b) It is permissible to make the runaway test with platform, but without the car bodywork, provided the test weight is equivalent to the weight of the car bodywork plus contract load.

This test should be carried out in the presence of the representative of the insurance office concerned or a qualified engineer, who shall issue the certificate of fitness.

13 (c) The maximum stopping distances of cars with safety gears of types G.W.C and F.G.C with contact load in the car, and the minimum stopping distances with the attendant only in the car, shall be as follows:

Speed Ft/min	**Max Distance with Contract Load**		**Min Distance with Attendant Only in Car**	
	Type G.W.C	Type F.G.C	Type G.W.C	Type F.G.C
300	7' 0"	1' 9"	1' 6"	0' 6"
400	7' 9"	2' 6"	1' 8"	0' 9"
500	8' 9"	3' 6"	1' 10"	1' 0"
600	10' 0"	4' 9"	2' 1"	1' 3"
700	11' 3"	6' 6"	2' 4"	1' 6"
800	12' 3"	8' 3"	2' 8"	1' 9"

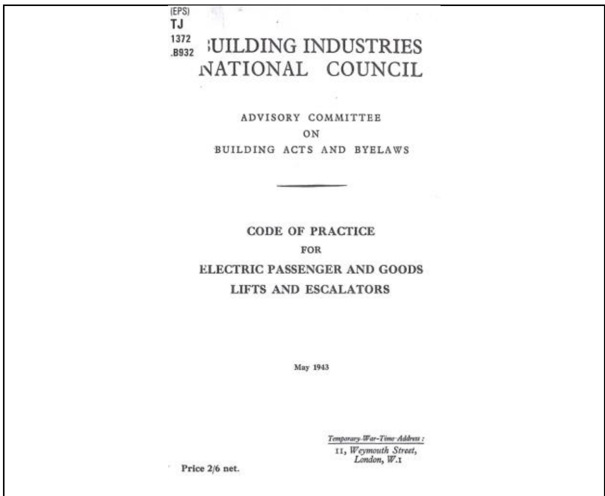
13(d) Stopping distance shall mean the actual slide as measured by the marks on the guides.

13(e) The runaway test shall be made by the lift maker with all electrical apparatus intact, except for the overspeed contact or cut out on the governor. For lifts operating directly from alternating current the governor shall be tripped by hand at the maximum speed obtainable.

13(f) Safety gears shall be examined thoroughly at least annually by the insurance company concerned or a qualified engineer, when the general condition of the working arts, sliding surfaces etc must be approved.

13 (g) At such examination the safety gear shall be applied with the car stationary and the car lowered to ensure the safety gear functions correctly.

6.2 Building Industries National Council, Code of Practice for Electronic Passenger and Goods Lifts and Escalators, 1943



UILDING INDUSTRIES
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ADVISORY COMMITTEE
ON
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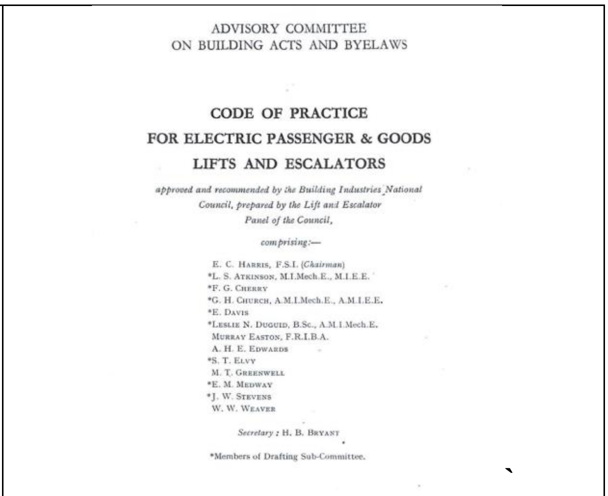
CODE OF PRACTICE
FOR
ELECTRIC PASSENGER AND GOODS
LIFTS AND ESCALATORS

May 1943

Temporary War-Time Address:
11, *Weymouth Street,*
London, W.1

Price 2/6 net.

Fig 6 The 1943 Code of Practice



ADVISORY COMMITTEE
ON BUILDING ACTS AND BYELAWS

CODE OF PRACTICE
FOR ELECTRIC PASSENGER & GOODS
LIFTS AND ESCALATORS

approved and recommended by the Building Industries National Council, prepared by the Lift and Escalator Panel of the Council,

comprising:—

E. C. Harris, F.S.I. (*Chairman*)
*L. S. Atkinson, M.I.Mech.E., M.I.E.E.
*F. G. Cherry
*G. H. Church, A.M.I.Mech.E., A.M.I.E.E.
*E. Davis
*Leslie N. Duguid, B.Sc., A.M.I.Mech.E.
Murray Easton, F.R.I.B.A.
A. H. E. Edwards
*S. T. Elvy
M. T. Greenwell
*E. M. Medway
*J. W. Stevens
W. W. Weaver

Secretary: H. B. Bryant

*Members of Drafting Sub-Committee.

Fig 7 Members of the 1943 panel

The preface to the 1943 edition makes interesting reading and unusually by modern standards makes specific reference to the passing of one of the committee members.

PREFACE

(TO SECOND EDITION, 1943)

The publication of the Code of Practice for the Installation of Lifts and Escalators in 1935 was most favourably received not only by the Industry but by engineers, architects, government departments, local authorities, insurance companies and all parties interested in the provision of a recognised degree of safety in these important features of modern buildings and public works.

As stated in the Preface to the First Edition, it was to be expected that experience of its application would call for a review of the Code after a reasonable period of operation. In view of this position, the Panel of the Council has been maintained, and in 1940 approached the subject of revision, with the result that the present revised edition of the Code is presented.

The Drafting Committee have carefully considered every suggestion for the improvement and clarification of the document from whatever source it may have emanated, and it is hoped that the usefulness of the Code as now issued will be increased by the amendments made. The Panel will continue to be at the service of the Council, and any suggestions received from time to time will be noted for consideration at the next period of revision.

It will be noticed that the sequence of construction has been more closely followed in re-arranging the clauses, as in the definitions, whilst useful graphs have been introduced to ascertain carrying capacity for passenger lifts. The diagrams on page 35 illustrate more clearly than any description the usage of certain terms and the provision to be made for equipment involving increased pit accommodation where high speed lifts are contemplated.

The Council and its Panel wish to record their great indebtedness to the late Mr. Rendell Davies, B.Sc., whose death occurred when the present revision was nearing completion, and who had so ably acted as Chairman of the Drafting Committee since its inception. He combined a wide knowledge of the subject with tireless energy and his technical assistance was invaluable. His passing was keenly felt by all his colleagues. Mr. L. N. Duguid, B.Sc., of the Factory Department of the Ministry of Labour and National Service was elected to preside over the Drafting Committee after the death of Mr. Davies, and the thanks of the Council and the Panel are extended to him for his good work in this emergency.

E. C. HARRIS,
Chairman,
Advisory Committee on
Building Acts and Bye-Laws

Fig 9 The preface to the 1943 code of practice.

The 1943 standard was far more specific and lost some of the quaint features that were in the 1935 standard such as the labelling of overspeed governors with brass labels although attendants in the car remained!

The section applicable to safety gears moved from section 12 to section 16 which stated:

16(a)(1) Every passenger and goods lift suspended by ropes shall be provided with a safety gear attached to the car frame and preferably placed beneath the car platform.

16 (a)(2) The safety gear shall be capable of stopping and sustaining the car with contract load.

16(a)(3) The safety gear shall operate to stop and sustain the lift car in the event of failure of all suspension ropes, or in the event of the lift car exceeding a predetermined speed in the descending direction when an overspeed governor is fitted.

16(b) No car safety gear shall be permitted to stop an ascending lift car. If an ascending lift car is to be stopped on account of overspeed, a safety gear shall be fitted to the counterweight for this purpose.

Note: An overspeed governor may be used to cause the motor control and brake control circuits to be opened in the event of overspeed in the up direction.

16(c) The car safety gear of every lift having a travel exceeding 20 ft. should be operated by an overspeed governor.

16(d) The application of the safety gear shall not cause the car platform to become out of level in excess of 1 in 24, measured in any direction.

16(e) The motor control and brake control circuits shall be opened at the time the safety gear is applied.

16(f) When the car safety is applied, no decrease in the tension of any rope for applying the safety gear, or motion of the lift car in the down direction shall release the car safety gear.
Note: It is permissible to release the safety gear by reversing the direction of the lift machine.

16(g)(1) It shall not be possible for vibration of the car frame to cause the safety gear to be applied.

16(g)(2) No safety gear shall depend upon the completion or maintenance of an electric circuit for its operation.

16(g)(3) Every safety gear shall be applied positively.

16(h)(1) safety gears of the instantaneous type may be used on car frames having a contract speed not exceeding 200 fpm.

16(h)(2) The tripping speed of governors used with instantaneous type safety gears shall not exceed 260 fpm.

16(i)(1) Any rope used for applying the safety gear shall be supported by its own pulley(s) and properly guarded. Such pulleys shall be mounted independently of any shaft carrying the lifting ropes.

16(i)(2) Such ropes shall not be less than ¼ in in diameter and shall be of steel or phosphor bronze.

16(j) The gripping surfaces of the safety gear shall be held clear of the guides during normal operation of the lift

16(k) Any levers or cams operated by shafts shall be fasted to such shafts by means of tapered pins in accordance with BS No 46 part 3, by means of sunk keys in accordance with BS No 46 Part 1, or by equivalent connection.

16(l) Safety gears shall be designed to grip each guide and to operate on both guides simultaneously.

16(m)(1) The rope attached to any safety gear actuating drum shall have not less than three turns of rope remaining in such drum after the safety jaws have gripped the guides and stopped the lift car.

16(m)(2) Bearings for actuating drums and screw shafts shall be of non-ferrous metal.

16(n) Any releasing carrier or other mechanism used for actuating the safety gear shall be carried by the car frame and not by the car enclosure.

16(o) When a release carrier is used to hold a governor rope clevis, such releasing carrier shall effect its purpose by means of a friction device.

The standard also introduced a table with lower rated speeds than the 1935 edition:

TABLE III

Governor Tripping Speed FPM	Maximum Stopping Distance	Minimum Stopping Distance	
	Car with contract load (or for counterweight)	Car with attendant only	Car with contract load (or for counterweight)
	WEDGE CLAMP SAFETY GEAR		
175	1’ 4”	0’ 10”	0’ 10”
200	1’ 6”	0’ 11”	1’ 0”
300	2’ 0”	1’ 0”	1’ 2”
400	2’ 10”	1’ 2”	1’ 7”
500	3’ 11”	1’ 5”	2’ 0”
600	5’ 2”	1’ 7”	2’ 5”
700	6’ 8”	1’ 11”	3’ 0”
800	8’ 6”	2’ 2”	3’ 7”
	FLEXIBLE CLAMP SAFETY GEAR		
175	0’ 10”	0’ 5”	0’ 6”
200	0’ 11”	0’ 6”	0’ 7”
300	1’ 7”	0’ 7”	0’ 8”
400	2’ 5”	0’ 8”	1’ 1”
500	3’ 5”	0’ 11”	1’ 6”
600	4’ 10”	1’ 2”	1’ 11”
700	6’ 5”	1’ 6”	2’ 5”
800	8’ 2”	1’ 10”	3’ 2”

16(p) Any part of a safety gear subject to tension, torsion or bending shall be made of steel.

16(q) The distance travelled by the lift car (or counterweight) between the tripping of the governor jaws and the safety gear jaws beginning to apply pressure to the guides shall not exceed 2 ft 6 in.

16 (r) The maximum and minimum stopping distances of lift cars with wedge clamp or flexible clamp safety gears shall be in accordance with table III above

16(s) The stopping distance is the actual slide as indicated by the markings on the guides made by the safety gear.

16(t)(1) Safety gears of the instantaneous type may be used on counterweights having a contract speed not exceeding 250 fpm.

16(t)(2) Provision shall be made to cause the application of the counterweight safety gear, when operated by an overspeed governor, at a greater speed than, but not more than 10 per cent greater that that at which the car safety gear is applied.

16(u) A pawl and ratchet shall not be held to constitute a sufficient safety gear.

This standard also introduced a separate section on overspeed governors by way of section 17 which stated:

17(a) Overspeed governors shall be placed where there is sufficient room for their proper operation and where they cannot be struck by the lift car or counterweight in the event of overrun

17(b) The overspeed governor shall be adjusted to cause application of the lift car safety gear at a speed within the limits given I table IV

TABLE IV

Contract Speed	**Governor tripping speed (Percentage of contract speed)**	
Ft. per min.	Minimum	Maximum
Up to 500	115% (1)	140%
Over 500 to 700	115%	133%
Over 700	115%	125%

(1) No governor shall be required to trip at less than 175 ft. per min,

17(c) Each overspeed governor shall be marked with its tripping speed in terms of car speed in feet per minute.

17(d) The motor control and brake control circuits shall be opened before or at the time the governor trips.

17 (e) Governor ropes shall not be less that 5/16 in in diameter and shall be of steel, or phosphor bronze and of suitable construction.

17(f) Governor ropes shall run clear of the governor jaws during normal operation of the lift

17(g) The arc of contact made by the governor rope and the governor sheave shall, in conjunction with a rope tension device, provide sufficient tractive effort to cause proper operation of the governor.

17(h) Governor jaws and their mountings shall be so designed that any cutting, tearing or deformation of the rope resulting from their application shall no6t prevent proper operation of the safety gear.

7 DEVELOPMENT OF BRITISH & EUROPEAN STANDARDS

Further work is required into researching of older standards and codes of Practice as there is clearly a gap between Otis demonstrating his safety gear in 1853 and the 1935 edition of BS2655-1.

Standards since 1970 have developed as follows:

1970 BS 2655-1:1970: Specification for lifts, escalators, passenger conveyors and paternosters. General requirements for electric, hydraulic and hand-powered lifts

1970 BS 2655-7:1970: Specification for lifts, escalators, passenger conveyors and paternosters. Testing and inspection

1979 BS 5655-1:1979, EN 81-1:1977: Lifts and service lifts. Safety rules for the construction and installation of electric lifts

1986 BS 5655-1:1986, EN 81-1:1985: Lifts and service lifts. Safety rules for the construction and installation of electric lifts

1986 BS 5655-10:1986: Lifts and service lifts. Specification for the testing and inspection of electric and hydraulic lifts

1995 BS 5655-10.1.1:1995: Lifts and service lifts. Specification for the testing and examination of lifts and service lifts. Electric lifts. Commissioning tests for new lifts

1995 BS 5655-10.2.1:1995: Lifts and service lifts. Specification for the testing and examination of lifts and service lifts. Hydraulic lifts. Commissioning tests for new lifts

1998 BS EN 81-1:1998+A3:2009: Safety rules for the construction and installation of lifts. Electric lifts

1999: PAS 32-1:1999: Specification for examination and test of new lifts before putting into service. Electric traction lifts

1999 PAS 32-2:1999: Specification for examination and test of new lifts before putting into service. Hydraulic lifts

2007 BS 8486-1:2007+A1:2011: Examination and test of new lifts before putting into service. Specification for means of determining compliance with BS EN 81. Electric lifts

2007 BS 8486-2:2007+A1:2011: Examination and test of new lifts before putting into service. Specification for means of determining compliance with BS EN 81. Hydraulic lifts

2014 BS EN 81-20:2014: Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. Passenger and goods passenger lifts

2014 BS EN 81-50:2014: Safety rules for the construction and installation of lifts. Examinations and tests. Design rules, calculations, examinations and tests of lift components

8 FACTORS AFFECTING SAFETY GEAR DESIGN

A number of factors seem to have driven safety gear design over the years.

- The desire to prevent an uncontrolled descent.
- The relationship between speed and safety gear design (principally to protect passengers against injury)
- The desire to protect against uncontrolled ascent as well as descent.

As the research progresses more categories may be identified although it currently appears that from 1853 onward for over a century it was simply a desire to prevent uncontrolled descent to allay passenger fears about this risk.

1970 BS 2655-1:1970: SPECIFICATION FOR LIFTS, ESCALATORS, PASSENGER CONVEYORS AND PATERNOSTERS. GENERAL REQUIREMENTS FOR ELECTRIC, HYDRAULIC AND HAND-POWERED LIFTS

This standard was published in 1970 and ended up with 6 amendments to its original form.

There were four separate sections on safety gear requirements which could be found in sections 2, 3, 5 and 6.

Safety gears shall comply with the following general requirements:

- Every passenger and goods lift shall be provided with a safety gear attached to the car frame and placed beneath the car platform.
- Safety gear shall also be provided on the counterweight where there is an accessible space beneath the travel of the counterweight.
- It shall be possible to release car safety gears by raising the car, and counterweight safety gears by raising the counterweight.
- Each car safety gear shall be operated by means of either a governor or a safety rope. All sheaves or pulleys in contact with any part of this rope, which is normally in motion at the same time as the car, shall have diameters at least 30 times the diameter of the rope.
- A car safety gear shall not operate to stop an ascending lift car. If an ascending lift car is to be stopped on account of overspeed then a safety gear shall be fitted to the counterweight for this purpose. Where an overspeed governor is used, it shall cause the motor control and brake control circuits to be opened in the event of overspeed in the upward direction.
- The application of the safety gear shall not cause the car platform to slope at more than 1 in 25 to the horizontal
- The motor control and brake control circuits shall be opened by a switch on the car safety gear before or at the time the safety gear is applied.
- When the car safety gear is applied, no decrease in the tension of any rope used for applying the safety gear, or motion of the lift car in the downward direction shall release the car safety gear.
- It shall not be possible for vibration of the car frame to cause a safety gear to be applied.
- No safety gear shall depend for its operation upon completing or maintaining an electric circuit.
- The gripping surfaces of a safety gear shall be held clear of the guides during normal operation of the lift.
- Any levers or cams operated by shafts shall be fixed to such shafts by means of welding, sunk keys or by equivalent positive connection.
- Safety gears shall be designed to grip each guide and to operate on the guides simultaneously
- Any shaft, jaw, wedge or support which forms part of a safety gear and which is stressed during its operation shall be made of steel or other ductile material
- The drive to a car governor rope shall be effected from the car frame.
- Any connecting device between a governor rope and car frame (or counterweight) that is intended to be released when the safety gear is applied shall be retained in its normal position by a spring-loaded device
- A pawl and ratchet shall not be used as a safety gear

9 LIFT SPEED AND SAFETY GEAR SELECTION

9.1 BS2655-1 (1970)

BS2655-1 (1970) stated 2.12.3 Safety gears of the instantaneous type may be used for lift cars having a contract speed not exceeding 0.75 m/s or 150 ft/min.

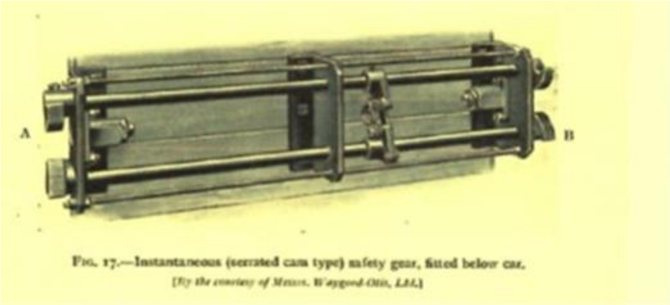


Fig 10: Waygood Otis instantaneous safety gear (source; Grierson)

9.2 BS5655-1 (1979)

There was a shift in the 1979 standard which introduced the buffered effect for the first time:

9.8.2.1 Car safety gear shall be of the progressive type if the rated speed of the lift exceeds 1.0 m/s. It can be (a) of the instantaneous type with buffered effect if the rated speed does not exceed 1.0 m/s (b) of the instantaneous type if the rated speed does not exceed 0.63 m/s

The buffered effect was rarely used but when it was it involved the sling having an additional and independent travelling section underneath it which had an instantaneous safety gear attached. This safety gear would operate and the forces were reduced by the lift car sling being separated from the safety gear by devices such as hydraulic pistons (rather like buffers) which would take the forces out of the operation.

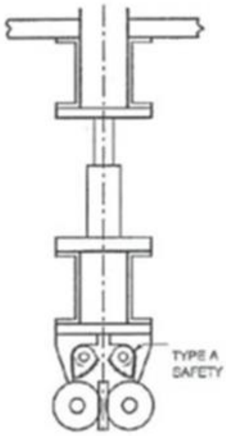


Fig 11: Buffered effect safety gear with a buffer between the car and safety gear (source: Inglis)

Different manufacturers came up with different designs for both instantaneous and progressive safety gears.

Examples of different arrangements from different companies can be seen below.

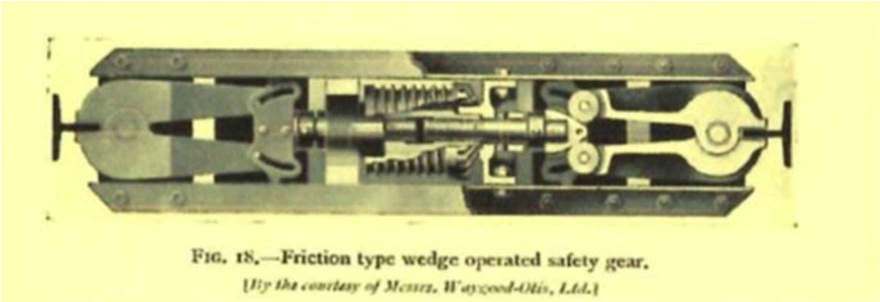


Fig 12: Otis Waygood wedge type progressive safety gear

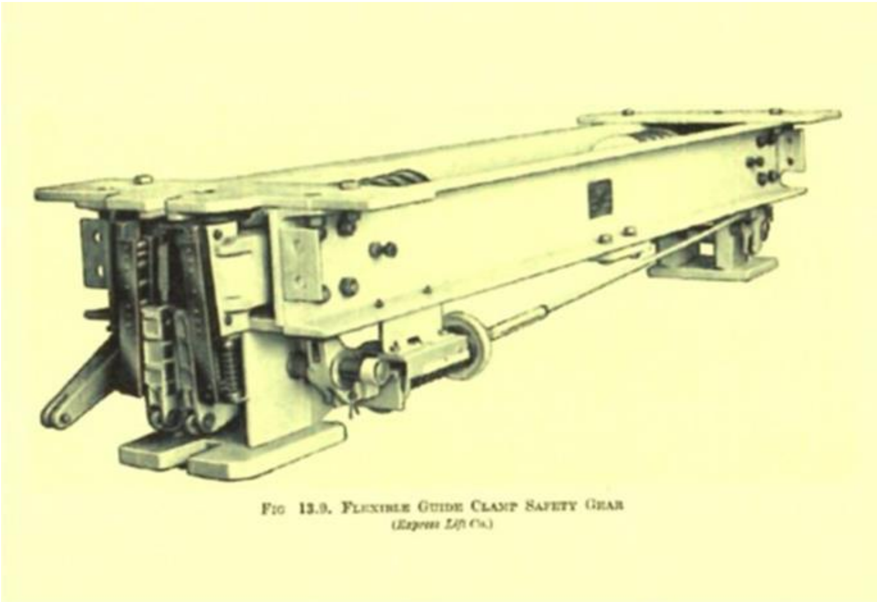


Fig 13: Express Lifts clamp type progressive safety gear (source: Philips [9])

9.3 BS5655-1 (1986)

This standard mirrored the BS5655-1 (1979) standard.

9.4 EN81-1 (1990) + A3 (2009)

Again, this standard mirrored the BS5655-1 (1979) standard.

9.5 EN81-20 (2014)

However, the publication of EN81-20 (2014) saw the end of the buffered effect with the wording being amended as follows:

5.6.2.1.2.1 Car safety gear (a) shall be of the progressive type or (b) may be of the instantaneous type if the rated speed of the lift does not exceed 0.63 m/s

The philosophy behind the change in speed between the 1970 and 1979 standards for instantaneous safety gears is not known however it can be seen that the EN81-20 (2014) standard limits instantaneous to a maximum speed of 0.63 m/s whereas the BS2655-1 (1970) standard allowed the higher speed of 0.75 m/s so despite the buffered effect being removed the reduced speed from the 1979 standard is still adopted.

10 FORCES

Initial considerations with respect to forces imposed on passengers may have caused the change.

Standards do not specifically state forces applied on a passenger during the operation of a safety gear.

The most relevantthat can be referred to is the forces permissible in the event of a buffer collision.

10.1 BS2655-1 (1970)

BS2655-1 (1970) simply stated in clause 3.4:

“Buffers shall be installed under all cars and counterweights. Springs buffers or buffers of rubber or timber may be used.”

By today’s standards a completely meaningless statement but clearly there is no consideration as to the forces permitted to be placed upon a passenger and no distinction between instantaneous or progressive safety gears. In particular it should be noted that timber buffers were permitted.

10.2 BS5655-1 (1979)

BS5655-1 (1979) saw the introduction of consideration into forces imposed on a passenger.

Clause 10.4.3.3 stated “With the rated load in the car, in the case of free fall, the average retardation during action of the buffers shall not exceed gn. Retardation of more than 2,5 gn shall not be longer that 1/25 of a second. The speed of impact on the buffers to be considered is equal to that for which the stroke of the buffer is calculated (see 10.4.3.1 and 10.4.3.2)

Whilst the introduction of forces into the standards came with the 1979 standard it is unlikely to account for the difference in speed with reference to safety gear speed between the 1970 and 1979 standards.

10.3 BS5655-1 (1986)

BS5655-1 (1986) mirrored the 1979 standard with the exception the $1/25^{th}$ of a second was replaced by 0.04 seconds thus eliminating the fraction for a decimal.

11 DIRECTION OF LIFT AND SAFETY GEAR SELECTION

11.1 BS2655-1 (1970)

As previously stated in BS2655-1 (1970) “A car safety gear shall *not* operate to stop an ascending lift car. If an ascending lift car is to be stopped on account of overspeed then a safety gear shall be fitted to the counterweight for this purpose.”

11.2 BS5655-1 (1979)

The wording changed in the 1979 standard to the following:

9.8.1.1 The car shall be provided with a safety gear capable of operating only in the downward direction and capable of stopping a fully laden car, at the tripping speed of the overspeed governor, even if the suspension devices break, by gripping the guides, and holding the car there.

It should be noted that the overspeed governor was introduced into the wording of standards at this point as a mandatory clause for all electric lifts including those with instantaneous safety gears albeit, as previously mentioned Charles Otis invented the flyball overspeed governor for progressive safety gears in 1878.

Prior to this BS2655-1 (1970) offered an overspeed governor as an option as follows:

2.12.3 The safety gear shall operate to stop and sustain the lift car with contract load in the event of failure of all suspension ropes or chains or their attachments, or in the event of the lift car exceeding a predetermined speed in the downward direction, when the safety gear is operated by an overspeed governor.

11.3 BS5655-1 (1986)

BS5655-1 (1986) adopted the same wording as the 1979 standard.

11.4 EN81-1 (1990) + A3 (2009)

It was not until EN81-1 (1998) Amendment 3 (2009) that the requirement to stop an ascending lift car came into being with clause 9.8.10 which stated:

9.10 A traction lift shall be provided with ascending car overspeed protection means conforming to the following:

9.10.1 The means, comprising speed monitoring and speed reducing elements, shall detect uncontrolled movement of the ascending car at a minimum 115% of the rated speed, and maximum as defined in 9.9.3, and shall cause the car to stop, or at least reduce its speed to that for which the counterweight buffer is designed.

11.5 EN81-20 (2014) varied the wording to as follows

5.6.1.1 Devices, or combinations of devices and their actuation shall be provided to prevent the car from (a) free fall, (b) excessive speed, either downwards, or up and down in the case of traction lifts, (c) unintended movement, with open doors (d) in the case of hydraulic lifts, creeping from a landing level.

12 CONCLUSION

The history of the safety gear is an interesting subject and it has been identified that there is a long gap of inactivity in design from 1853 to 1935 which requires further investigation. Sources thus far identified show development from a state of concern about the risk of falling to the quality of the fall should it happen with the introduction of acceptable forces relative to speed. Furthermore, the need to address other technical issues such as uncontrolled movement in the ascending mode have also caused developments in safety gear design. Research will continue to establish development of the safety gear from its initial design in 1853 to the present day.

REFERENCES

[1] Leroy A. Peterson, *Elisha Graves Otis 1811-1861 and his influence upon Vertical Transportation* (Presentation to the Newcomen Society American Branch in New York 1945)

[2] John Inglis, *Evolution of Safety Gear*, 1998 (Presented at Elevcon)

[3] Grierson, *Electric Lift Equipment for Modern Buildings*, Chapman & Hall, 1923

[4] British Standards Institute *Specification for lifts, escalators, passenger conveyors and paternosters part 1: general requirements for electric, hydraulic and hand powered lifts, 1970* BS 2655-1 (1970)

[5] British Standards Institute *Lifts & Service Lifts Part 1, safety rules for the construction and installation of electric lifts, 1979* BS5655-1 (1979)

[6] British Standards Institute *Lifts & Service Lifts Part 1, safety rules for the construction and installation of electric lifts, 1986* BS5655-1 (1986)

[7] British Standards Institute *inc Amendment A3, Safety rules for the construction and installation of lifts – part 1 electric lifts 1998* EN81-1 (1998)

[8] British Standards Institute *Safety rules for the construction and installation of lifts – lifts for the transport of persons and goods Part 20 passenger and goods passenger lifts, 2014* EN81-20 (2014)

[9] R S PHILIPS, *Electric Lifts*, 1939 (Pitman Publishing)

[10] Lee Gray, *A History of the Passenger Elevator in the 19th Century*, Lee Gray. (Elevator World, 2002)

BIOGRAPHICAL DETAILS

David Cooper is the Managing Director of UK based lift consultants LECS (UK) Ltd. He has been in the lift & escalator industry since 1980 and is a well-known author and speaker. He holds a Master of Philosophy Degree following a 5-year research project into accidents on escalators, a Master of Science Degree in Lift Engineering as well as a Bachelor of Science Honours degree, Higher National Certificate and a Continuing Education Certificate in lift and escalator engineering. He is a co-author of "*The Elevator & Escalator Micropedia*" (1997) and "*Elevator & Escalator Accident Investigation & Litigation"*. (2002 & 2005) as well as being a contributor to a number of other books including CIBSE Guide D. He is a regular columnist in trade journals worldwide including Elevation, Elevator World and Elevatori. He has presented at a number of industry seminars worldwide including 2008 Elevcon (Thessaloniki), 2008 NAVTP (San Francisco),1999 LESA (Melbourne), 1999 CIBSE (Hong Kong), 1999 IAEE (London), 1998 (Zurich), 1997 CIBSE (Hong Kong), 1996 (Barcelona) and 1993 (Vienna) as well as numerous presentations within the UK. He is also a Founding Trustee of the UK's Lift Industry Charity which assists industry members and/or their families after an accident at work. In 2012 David was awarded the silver medal by CIBSE for services to the Institution. David Chairs the Charity that runs the Lift Symposium and is an Honorary Visiting Fellow at The University of Northampton.