# The Science Behind Lift Codes & Standards

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**Abstract.** Codes and Standards at first glance appear to be an arbitrary collection of rules, regulations, and dimensions. However, most codes and standards are based on basic safety principles, known risks, and science.

The safety fundamentals behind codes and standards in ISO/TR 1107-1 for traction lifts are presented.

The risks to be addressed, as well as the persons and objects to be safeguarded, as defined in EN 81-1, are reviewed. Although EN 81-1 has been superseded by EN 81-20 and EN 81-50, the abbreviated list of risks in EN 81-1 is still valid and easier to understand.

The science, mostly physics, and how it is applied are explained in simple terms.

How the risks, safety fundamentals, physics, and standards are applied to safety gears, brakes, and buffers are explored.

## 1 INTRODUCTION

During my first week in the lift industry, I was introduced to both the State of California Elevator Safety Orders and the City of Los Angeles Elevator Code.

California had no minimum pit depth. For flexibility, I was instructed to ask for a 3'- 11" (1,194 mm) deep pit. However, the City of Los Angeles required a minimum pit depth of 4'– 0" (1,219 mm). I asked why Los Angeles wanted an extra 1" (25.4 mm) and was told that both codes require a pit ladder if the pit is 4' or deeper, and Los Angeles wanted a pit ladder for their older inspectors.

For the next thirty-three years, I assumed codes were just a set of arbitrary rules that had to be followed to successfully get through an inspection. Then I took a course at the University of Northampton titled *Codes and Standards* and learned that there was science behind most of the standards [1].

## 2 RISKS TO BE SAFEGUARDED

EN 81-1 identifies the following risks that need to be addressed and mitigated [2]:

a) shearing
b) crushing
c) falling
d) impact
e) trapping
f) fire
g) electric shock
h) failure of material due to:
    1) mechanical damage
    2) wear
    3) corrosion

Additionally, EN 81-1 requires loads in the car and the following persons to be safeguarded:

a) users
b) maintenance and inspection personnel
c) persons outside the lift well, the machine room and pulley room (if any)

## 3 ASSUMPTIONS

ISO TR 11071:2004 Comparison of worldwide lift safety standards Part 1: Electric lifts (elevators) states that the world's safety standards for lifts are based on a common set of assumptions about the following [3]:

1. Safe operation assured to 125% of rated load
2. Failure of electrical safety devices
3. Failure of mechanical devices
4. Imprudent acts by users
5. Neutralisation of safety devices during service
6. Car speed linked to frequency of mains (the frequency of the three-phase electrical supply)
7. Horizontal forces exerted by a person
8. Retardation

Each of these assumptions will be reviewed.

### 3.1 Safe operation assured to 125 % of rated load

It seems very logical to assume that passenger lifts can be overloaded. The amount to which they can be overloaded with people is limited by platform area.

For example:

1. The maximum platform area permitted by EN 81-20 for a 630 kg passenger lift is 1.66 m² [4].
2. A 630 kg lift is rated for 8 passengers.
3. It is assumed that a typical passenger will have a mass of 75 kg and occupy 0.21 m² of cabin floor area.
4. Eight passengers would then require a platform area of 1.68 m² (8 * 0.21).
5. A 630 kg lift must be able to safely transport a 25% overload or 786 kg.
6. The additional 158 kg represents 2 additional passengers (2 * 75).

In the example above, the lift can be seen to be fully occupied with 8 passengers. Therefore, it would be difficult for 10 passengers to enter this lift.

### 3.2 Failure of electrical safety devices

Electrical safety devices are typically homologated by a Notified Body or an equivalent organisation. Therefore, it is assumed that if properly manufactured, installed, maintained, and most importantly, inspected, they will function properly when needed.

### 3.3 Failure of mechanical devices

Except in accidents involving suspension means or partial brake failure, mechanical components are assumed not to deteriorate to a hazardous condition before the need for replacement is detected. This applies when they are built and maintained in accordance with good practice and safety standards.

### 3.4 Imprudent acts by users

It must be assumed that users of lifts will misuse lifts and therefore, lift engineers should consider this in their designs.

### 3.5 Neutralisation of safety devices during servicing.

It is understood that service technicians must at times use jumpers to bypass door locks, etc. Jumpers can inadvertently be left in place when a lift is returned to service. To prevent this condition, BS EN 81-1: 1998 +A3:2009 requires a Landing and Car Door Bypass Device. The device is easier to use than a jumper, and the car will not run on automatic with the device enabled.

### 3.6 Car speed linked to frequency of mains

Prior to the 1980s, many slow speed lifts used single or two speed AC motors. These motors were known as asynchronous motors or as squirrel cage motors, and operated at a speed that approximated a multiple of the supply frequency. The following equation can be used to define the motor speed in revolutions per minute (rpm) [5]:

$$N_s = \frac{60 \times f}{p \div 2} \quad (1)$$

Where: $N_s$ represents synchronous speed in rpm

$f$ represents frequency of the AC supply mains

$p$ represents the number of poles of the motor

See Figure 1.

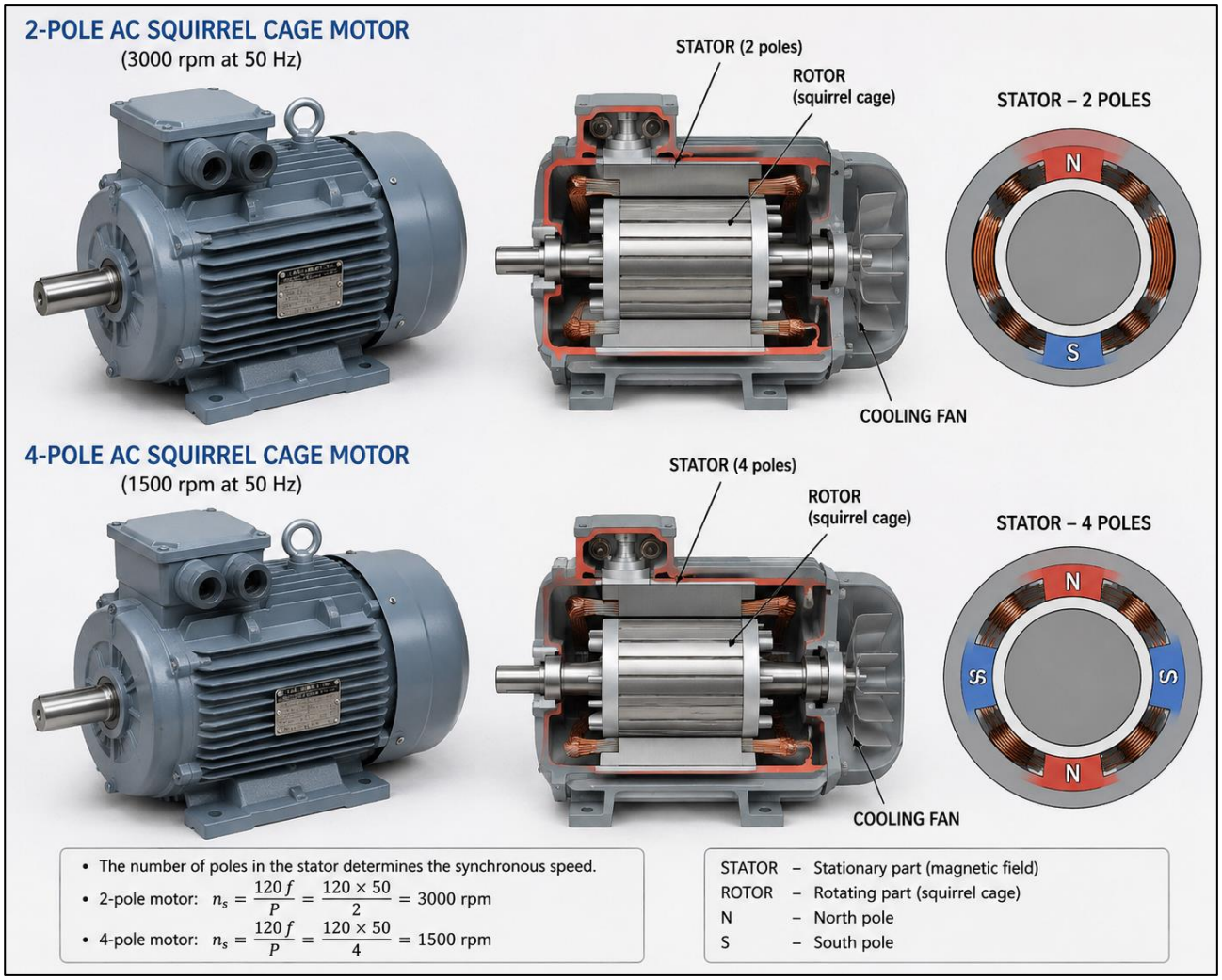



**Figure 1 [6]**

The actual speed of an asynchronous motor depends on the load [7]. If a fully loaded lift is going up, the motor rpm will be approximately 5% less than the synchronous speed. The same fully loaded lift travelling down will travel approximately 5% faster than synchronous speed.

If an AC machine is designed to operate at 1 m/s fully loaded in the up direction with 5% slip, then it will run in the down direction fully loaded at 1.1 m/s or 110% of rated speed.

The minimum tripping speed for governors is 115 % of the rated speed of a lift [4]. This speed prevents governors from tripping when the overspeed is due to the characteristics of a squirrel cage motor, whilst correctly sensing a true overspeed or loss of suspension.

### 3.7 Horizontal forces exerted by a person

One person can exert either of the following horizontal forces at a surface perpendicular to the plane at which the person stands [3]:

a) static force: 300 N.

b) force resulting from impact: 1,000 N.

When one imagines a 75 kg person either leaning against a cabin wall or hoistway door, the 300 N force seems reasonable, as does an impact force of 1,000 N.

Static forces of short duration may be exerted by the simultaneous deliberate acts of several people located immediately adjacent to each other at an interval of every 300 mm along the width of surfaces such as doors and cabin walls.

For this reason, codes and standards have rigorous static and dynamic tests of entrance doors, cabin doors, and cabin walls [3, 8].

### 3.8 Retardation

People have been found to be capable of withstanding an average vertical retardation of 1g (9.81 m/s²), such as during an emergency stop of a lift. Additionally, higher transient retardations have also been tolerated successfully.

ISO TR 11071 states that historically, this 1g value is not been shown to be unsafe for a vast majority of people [3].

This retardation assumption applies to every device that retards the velocity of a lift in all the world's codes.

## 4 STANDARDS APPLICATIONS

The following are examples of how Codes and Standards address risks and persons to be safeguarded based on the assumptions previously detailed.

### 4.1 Safety Gear, Progressive

Risk: Impact, Falling

Persons to be safeguarded: Users

Assumptions: Retardation, Car speed linked to frequency of mains

Discussion: Progressive safety gears are required to bring a fully loaded car to a stop with an average retardation rate of between 0.2 $g_n$ and 1 $g_n$. The minimum safety application velocity is 1.15$v_n$.

The reason EN 81 specifies a retardation rate of between 0.2 $g_n$ and 1 $g_n$ is to accommodate an empty car and a fully loaded car. If a fully loaded car decelerates at 1$g_n$, then an empty car would decelerate at a significantly higher rate.

Example: Calculate the force required to decelerate a fully loaded lift with a capacity of 1,000 kg (Q) and an empty car weight of 1,700 kg (P) at a rate of 1 $g_n$. Newton's Second Law of Motion states the following [9]:

$$F = ma \tag{2}$$

Where: $F$ represents force in Newtons

$m$ represents mass in kilograms

$a$ represents acceleration in meters per second squared

$g_n$ represents the gravitational acceleration or 9.81 m/s².

In the case of a free-falling lift:

$$a = (g_n + k) \tag{3}$$

Where $k$ represents the deceleration rate of the free-falling lift.

The retarding force in this case will equal 2,700 x 19.62, or 52,972 Newtons.

If the mass in the car is changed to 0 kg, then the total mass equals 1,700 kg, and if the retarding force of the safety gear remains 52,972 N, then the deceleration rate equals 2.18 $g_n$.

Solving for the maximum retarding force that can decelerate the empty car at $1g_n$ yields a value of 33,354N.

A retarding force of 33,354N would decelerate the fully loaded car at 2.54 $g_n$.

The example shown here has been simplified for clarity. A real example would include rope and compensation masses, kinetic and potential energy dissipation, and other variables.

The EN 81 code gives a reasonable range of deceleration rates so both the fully loaded and empty car can operate safely considering a more complete and complex set of variables.

### 4.2 Energy Dissipation Buffers

Risk: Impact

Persons to be safeguarded: Users

Assumptions: Retardation, Car speed linked to frequency of mains

Discussion: Energy dissipation buffers are required to bring a fully loaded lift car or counterweight travelling $1.15v_n$ to a stop at a deceleration rate of no more than $1g_n$. The retardation requirement is based on the retardation assumption, whilst the velocity requirement is based on the car speed being linked to the frequency of mains assumption.

### 4.3 Overspeed Governor

Risk: Impact, falling

Persons to be safeguarded: Users

Assumptions: Retardation, Car speed linked to frequency of mains

Discussion: Overspeed governors have a minimum tripping speed of $1.15v_n$. This is based on the car speed being linked to the frequency mains. A fully loaded car travelling down can exceed $v_n$ . The minimum tripping speed requirement is to avoid setting the safety gear whilst the suspension means are intact.

Overspeed governors have a maximum tripping speed of approximately 1.25 $v_n$. This speed limit reduces the quantity of energy that must be dissipated by the safety gear and reduces the forces to which the lift equipment will be subjected.

The overspeed governor must be fitted with an electrical switch that will disconnect the hoist machine from the electrical mains and cause the mechanical brake to be applied. Whilst not a requirement of EN 81, this switch is commonly set at 1.15 $g_n$.

### 4.4 Mechanical Brake

Risk: Impact, falling

Persons to be safeguarded: Users

Assumptions: Retardation, Safe operation assured to 125 % of rated load, Failure of material (partial brake failure)

Discussion: Brakes are required to stop and hold 125% of rated load with a maximum deceleration rate of $1 g_n$.

Two braking devices are required because it is envisioned that a partial brake failure can occur. A single mechanical brake must decelerate the car.

## 5 DISCUSSION

The components reviewed in the previous section safeguard passengers from a series of events, including loss of suspension, overspeed conditions, and failure to stop at terminal landings as follows:

a) Loss of suspension: The governor detects a loss of suspension and activates the safety gear at 1.25 $v_n$. The safety gear brings the car to a stop at a deceleration rate no more than 1 $g_n$.
b) Overspeed in the down direction, suspension intact: The governor detects the car speed is above 115% of $v_n$, and disconnects power to the motor and brake. The brake brings the car to a stop at a deceleration rate no more than 1 $g_n$.
c) Overspeed in the down direction with partial brake failure: The buffer brings the car to a stop at a deceleration rate no more than $1 g_n$.
d) The car fails to stop at the lowest landing at a speed below 115% $v_n$: The buffer brings the car to a stop at a deceleration rate no more than $1 g_n$.

These components safeguard the passengers or goods inside the cabin from zero to 100% of capacity.

## 6 CONCLUSIONS

This paper has shown that codes and standards for lifts are not just a set of arbitrary rules that must be followed to successfully get through an inspection, but rather a set of standards that are based on risks to be mitigated and a group of time-tested assumptions.

## REFERENCES

[1] *Codes and Standards*, University College Northampton, Northampton (1999)

[2] British Standards Institute. (2009). *BS EN 81-1:2009 Safety rules for the construction and installation of lifts - Part 1: Electric lifts.* BSI Standards Limited

[3] International Standards Organization. (2004). *ISO TR 11071:2004 Comparison of worldwide lift safety standards —Part 1: Electric lifts (elevators)*

[4] British Standards Institute. (2020). *BS EN 81-20:2020 Safety rules for the construction and installation of lifts – Lifts for the transportation of persons and goods - Part 20: Passenger and goods passenger lifts.* BSI Standards Limited

[5] *Speed control of Induction Motor.* Available from: https://www.eeeguide.com/speed-control-of-induction-motor/ last accessed: 23 May 2026

[6] Figure 1. Comparison of 2-pole and 4-pole squirrel cage AC induction motors. Source: Author-generated using ChatGPT (OpenAI), 2026.

[7] *Braking of Induction Motor.* Available from: https://www.eeeguide.com/braking-of-induction-motor. Last accessed: 24 May 2026.

[8] ASME A17.1 (2022) Safety Code for Elevators and Escalators. ASME, U.S.A

[9] Giancoli, D *Physics: Principles with Applications.* Prentice Hall, New Jersey, 2005

## BIOGRAPHICAL DETAILS



Rory Smith is a Consultant at Peters Research Ltd. He has over 57 years of lift industry experience, during which he held positions in research and development, manufacturing, installation, service, modernization, and sales. His areas of special interest are Machine Learning, Operations Management, Traffic Analysis, dispatching algorithms, and ride quality. Numerous patents have been awarded for his work.