Technical Investigation Report on Lift Incident at Selwyn Factory Building, 404 Kwun Tong Road, Kwun Tong, Kowloon

Electrical and Mechanical Services Department

April 2015

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Executive Summary

On 8 October 2014 at around 8:40 pm, the lift No. 1 at Selwyn Factory Building, 404 Kwun Tong Road, Kwun Tong, Kowloon, was reported to have slipped downward from 12/F to the bottom of the lift shaft, causing injury to 29 passengers. The maximum design capacity of the lift was 1600kg or 21 passengers.

The Electrical and Mechanical Services Department (EMSD) had completed the technical investigation with the assistance of independent experts engaged to identify the causes of the incident. The investigation revealed that the incident was initiated by an excessive overloading with 31 passengers packed into the lift car. When the lift loaded with 13 passengers landed on the 12/F, 18 more passengers subsequently packed into the lift car and began to slip downwards from 12/F, 2 passengers swiftly left the lift car but the overloading condition had already exceeded the rated load. The lift car gradually increased in speed and finally stopped after hitting the buffer at the bottom of the lift shaft.

The investigation indicated that there was no suspension rope breakage and the overload visual and audible alarms functioned properly. The lift brake system had been applied since the lift car stopped at the 12/F landing level. With passengers entering and leaving the lift car, the lift car was subject to a total load in the range of 125.5% to 132% of the rated load. The lift brake system, which was rated to handle up to 125% of the rated load, was unable to keep the lift car stationary at the 12/F floor. The lift car started to slip downward and gradually increased in speed. The overspeed governor detected the overspeed and triggered the safety gears. With the design operating conditions exceeded due to overloading, although the brake and safety gears had reduced the downward speed of the lift car, the lift continued to slip downward and was finally stopped after hitting the buffer at the bottom of the lift pit.

Technical Investigation Report on Lift Incident
at Selwyn Factory Building, 404 Kwun Tong Road, Kwun Tong, Kowloon

1. Objectives

1.1 This report presents the findings of the technical investigation conducted by the Electrical and Mechanical Services Department ("EMSD") on the lift incident occurred at Selwyn Factory Building, 404 Kwun Tong Road, Kwun Tong, Kowloon on 8 October 2014.

2. Background of the Incident

2.1 EMSD received a notification from the call centre of the Fire Services Department at around 8:40 pm on 8 October 2014 that a total of 29 passengers were reported injured inside lift No. 1 at Selwyn Factory Building, 404 Kwun Tong Road, Kwun Tong, Kowloon ("the lift"). EMSD staff arrived at the scene at around 9:30 pm on the same day to carry out investigation into the incident.

2.2 The concerned lift No. 1 was designed with a capacity of carrying a maximum of 1600kg or 21 passengers. At the incident moment, when the lift loaded with 13 passengers landed on 12/F, 18 more passengers subsequently packed into the lift car so that the number of passengers increased to 31. 2 of them swiftly left the lift when it just began to slip downward. All 29 passengers inside the lift were rescued by firemen and admitted to hospitals.

3. Technical Information of the Lift Involved in the Incident

3.1 The lift was driven by a variable voltage variable frequency (VVVF) traction machine, with a rated speed of 1.0 metre per second (m/s) and a rated load of 1 600 kg (21 persons), serving G/F, 1/F to 14/F of the building. The total travel of the lift was about 45 metres (m).

3.2 The lift was suspended by ten suspension ropes, each with a nominal diameter of 13 millimetres (mm). The lift machine room housing the traction machine of the lift was adjacent to the lift shaft.

3.3 Technical details of the lift are summarised as follows:

Make	:	Falconi/Nikkin
Drive Control	:	Variable voltage variable frequency electric motor
Door Control	:	Horizontal centre opening
Rated Speed	:	1.0 metre per second
Rated Load	:	1 600 kilograms
Rope Ratio	:	1 to 1
Floor Served	:	G/F, 1/F to 14/F
Year of 1st Installation	:	1979
Year of Major Alteration	:	2011
Date of Last Examination by Registered Lift Engineer	:	3 January 2014
Date of Last Examination with Load by Registered Lift Engineer	:	26 January 2013

3.4 The Appendix illustrates basic construction of a lift and the safety protection systems.

4. Approach of Investigation

4.1 EMSD conducted the technical investigation with a view to identifying the causes leading to the incident. The approach of the investigation is outlined below:

(i) review and analyse the CCTV footage to assess the extent of overloading and the speed profile of the lift during the course of the incident;

(ii) measure the weight of the passengers involved in the incident to assess the extent of overloading;

(iii) inspect, check and analyse the critical lift components with the assistance of independent experts, including the machine brake, safety gears, guide rails and overspeed governor;

(iv) retrieve the status log from the lift controller;

(v) interview and take statements from relevant personnel for collecting information related to the incident, including the concerned registered lift contractors, registered lift engineer and registered lift workers, passengers involved in the incident, and responsible person of the lift.

(vi) review and analyse relevant records including logbook, maintenance records, test and examination report, and relevant correspondence.

5. Observations and Findings

CCTV Footage

5.1 CCTV installed inside the lift captured the course of the incident. A critical review of the CCTV footage revealed that the lift car remained stationary when 29 passengers stayed inside it. The lift car began to slip downward slowly right after 2 more passengers packed into the lift (i.e., a total of 31 passengers inside the lift triggered the initial unintended downward movement). 2 passengers managed to leave the lift car swiftly right after it started moving downward and the lift continued to slip with 29 passengers remained inside. The lift car finally stopped when it hit the spring buffer installed at the bottom of the lift shaft. It was also noted that the lift car door remained open throughout the travel.

Overloading Condition

5.2 To assess the actual load on the lift at the time of the incident, all 31 passengers including their belongings were weighed, including the 2 passengers who managed to leave the lift when the lift car just began to slip downward. Every endeavor had been made to measure the weights as soon as possible after the incident so as to ascertain the actual loading condition at the time of the incident. 58% of the measurements were made within 6 days, and all the measurements were completed in 17 days. Due to lapse of time, the measurements may not be able to completely reflect the actual loading condition (e.g., only confirmed and traceable belongings could be weighed, and as some passengers were undergoing treatment their measured weights might be lower than that at the incident moment). It is envisaged that the measured weights are on the low side and may only reflect the minimum load on the lift car at the incident moment. The total weight of the 29 passengers (who still remained inside the lift car during the course of the incident) was 1 865 kg (116.6% of the rated load). The weight of the other 2 passengers was 143kg. The total static weight of the 31 passengers was calculated to be 2 008 kg (125.5% of the rated load).

5.3 Passenger entering and leaving a lift car would exert a dynamic load onto the lift car at a level over and above the body weight of the passenger. To assess the level of such transient load, a laboratory test on the transient force exerted on the ground during walking was conducted at the Hong Kong Polytechnic University Human Locomotion Laboratory. Test results indicated that (1) the transient load exerted on the ground surface when a person stepped onto a surface normally was about 10% to 20% higher than the normal body weight of the person; (2) the transient load exerted on the ground surface when a person stepped out from a surface rapidly was about 53% to 72% higher than the normal body weight of the person.

5.4 CCTV footage indicated that the lift car remained stationary when the first 29 passengers settled inside the lift car. The lift car started to slip downward right after the last 2 persons (with total body weight 143 kg) stepped into the lift car normally. The 2 persons then swiftly left the car upon noting that the lift car was descending gradually. The total static load and the transient dynamic load due to the passengers carried at that instance were estimated as follows:

Static Load (29 passengers inside lift car)	=	1865 kg

Transient Step Load Analysis:

The last 2 passengers stepping into lift car normally		
(transient increase of 10% to 20% of normal weight)	=	143 kg x 1.10 to 1.20
	=	157 to 172 kg
The last 2 passengers stepping out from lift car swiftly		
(transient increase of 53% to 72% of normal weight)	=	143 kg x 1.53 to 1.72
	=	219 to 246 kg
Transient load exerted on lift car	=	1865 + 157 to 172
before it began to slip down at 12/F	=	2022 to 2037 kg
	=	126% to 127% of rated load
Transient load exerted on lift car	=	1865 + 219 to 246
when 2 passengers swiftly left the lift car at 12/F	=	2084 to 2111 kg

= 130% to 132% of rated load

It was estimated that the lift car was subject to a **<u>transient load in the range of 126 to 127% of the rated load</u>** and then it began to slip downward at 12/F. When the lift car had started slipping downward, the lift car was subject to **<u>a higher transient load in the range of 130 to 132% of the rated load</u>** at the instance when the 2 passengers was leaving the lift car swiftly at 12/F. Under such adverse overloading operating conditions, the lift brake system failed to hold the lift car and the lift started to slip downward.

<u>Overspeeding Condition</u>

5.5 The position of the lift car against time during the course of the incident was estimated based on the CCTV footage.

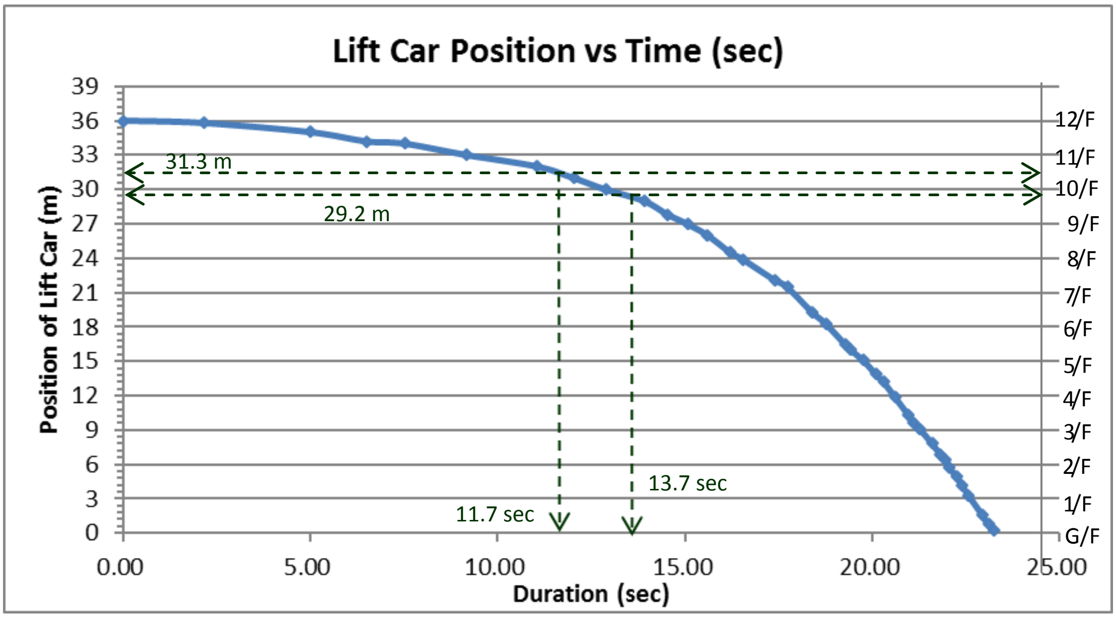


Figure 1 Lift Car Position against Time

5.6 The velocity profile (Figure 2) of the lift against time during the course of the incident was estimated based on the CCTV footage.

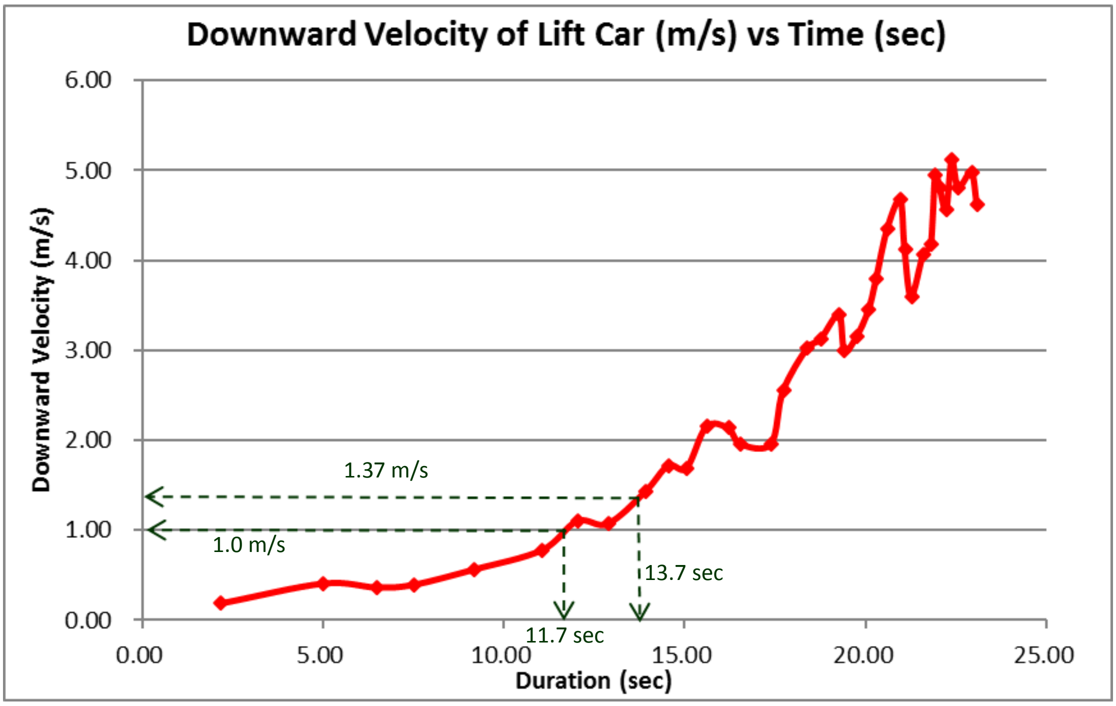


Figure 2 Velocity Profile of Lift No. 1

5.7 The velocity of the lift car in the first 5 seconds was found increasing gradually. The lift car continued to accelerate and attained its rated speed (i.e. 1.0 m/s) at around 11.7 seconds after it began to slip downward at 12/F. The lift car further attained the tripping speed of the governor system (i.e. 1.37 m/s, see para. 5.19) at around 13.7 seconds. The velocity of the lift car continued to increase and the maximum velocity attained was 5.1 m/s at the time before it hit the buffer at the bottom of the lift pit. Some signs of momentary reduction in the lift car velocity were noted at approximately 16 seconds, 20 seconds and 22 seconds after the initial downward movement.

5.8 The velocity profile indicated that both the lift brake system and the safety gears were exerting braking forces to stop the lift movement but were unable to stop the downward movement of the overloaded lift.

<u>Suspension Ropes</u>

5.9 All 10 suspension ropes were inspected after the incident and they were in good condition. There was no breakage of suspension ropes.

Overload Device

5.10 According to information provided by the passengers, both visual and audible overload alarm signals had been activated inside the lift car before the lift car began to slip downwards. The lift car door remained open throughout the course of the incident. This complies with the requirement in the Code of Practice on the Design and Construction of Lifts and Escalators ("Design Code") issued by EMSD, which specifies that the overload device shall prevent the power operated doors from closing. This provision is to allow passengers to leave the overloaded lift car after noticing the overload audible and visual alarms.

Lift Brake System

5.11 The Design Code requires that the lift brake system should be capable of stopping the machine when the lift car was travelling downward at its rated speed and with a load equivalent to 125% of its rated load. The lift brake system has to be tested annually under no-load condition, and overloading examination at 125% of the rated load is conducted at 5-yearly interval. The last overloading examination on the lift brake system was conducted on 26 January 2013.

5.12 During the on-site inspection after the incident, it was noticed that the brake arms remained at its activated position. CCTV footage confirmed the lift brake system was unable to stop the downward movement of the lift car even though the brake system had been activated throughout the course of the incident.

5.13 Para. 5.4 of this report stated that the initial downward movement of the lift car was caused by an excessive static and transient load exerted on the lift car (126% to 127% of the rated load) when a total of 31 passengers stayed inside it. The load exceeded the design operating conditions of the lift brake system and caused the lift car to slip downward. CCTV footage revealed that the lift car descended gradually in the first 5 seconds during which the system was subject to a transient load in the range of 130% to 132% of the rated load. The velocity profile of the lift indicated the lift brake system had been activated at the time of the starting of slipping at 12/F.

5.14 Before the lift started to descend, the brake had already been applied. Under the excessive overloaded condition, the brake could not hold the overloaded car stationary and it started to descend. The coefficient of friction under static condition was higher than that under dynamic condition. Even after the 2 passengers had left the lift, the frictional force between the brake pad and the brake drum had decreased under dynamic condition, and the lift continued to slip down with 29 passengers inside the lift.

5.15 A laboratory analysis of the brake pad was conducted by our appointed material expert. The brake pad surfaces were considered normal and did not show any burn marks or uneven abrasion. The thickness of the brake pads at both left and right sides of the traction machine was measured to be 6 mm thick, which was similar to the required thickness of a new brake pad (based on information from the O&M Manual produced by the lift manufacturer). The brake pad surfaces were also examined using a stereomicroscope and the surfaces were found normal.

Safety Gears

5.16 The Design Code requires that safety gears should be capable of operating in the downward direction to stop a car carrying rated load at the tripping speed of the overspeed governor by gripping the guide rails and holding the lift car there.

5.17 The Appendix illustrates how the governor system and the safety gears function together to stop an overspeed lift car.

5.18 For the governor, according to the on-site inspection findings, the electrical switch of the overspeed governor was activated. The status log of the lift machine controller also indicated that the safety circuit was triggered during the course of the incident. Such evidence indicated that the overspeed governor had already been activated.

5.19 A governor tripping speed test was conducted to check the tripping speed of the overspeed governor. The tripping speed was measured to be 1.37 m/s. During the on-site test, the electrical switch of the overspeed governor was found triggered instantaneously right before the triggering of the mechanical switch. Test results indicated that the governor functioned properly and the tripping speed setting was in compliance with the requirement specified in the Design Code issued by EMSD.

5.20 As described in para. 5.7, the lift car was generally accelerating downwards and there were three momentary reductions in the car velocity during the downward travel, reflecting that the activated overspeed governor had triggered the operation of safety gears. Having considered the overloaded condition of the lift car, which was at

116.6% of the rated load and therefore exceeded the design operating conditions of the safety gears specified in the Design Code, the safety gears had reduced the downward speed of the lift car but could not stop the lift car after the tripping speed (1.37 m/s) of the system was reached. It continued to slip downward until it reached the buffer at the bottom of the lift pit.

5.21 The investigation found that the maintenance contractor had not deployed sufficient resources to maintain the lift and the governor rope had loosened. EMSD is considering taking disciplinary action against suspected misconduct or neglect in professional respect of the concerned lift contractor, ThyssenKrupp Elevator (HK) Ltd.

6. Conclusions

Based on the findings of the investigation, the following conclusions are drawn:

6.1 The incident was initiated by an excessive overloading condition in which a total of 31 passengers packed into the lift, which was designed for a rated capacity of 21 passengers only.

6.2 The overload device functioned in accordance with the Design Code requirement. Both visual and audible alarm signals were triggered inside the lift car to alert the passengers before the lift car began to slip downward.

6.3 Both the static and sudden excessive transient load exerted on the lift car exceeded 125% of the design load and the design operating conditions of the brake. The lift brake system was unable to cater for the excessive overload and subsequently failed to maintain the lift car stationary. The car began to slip downward with increasing speed.

6.4 The overspeed governor was activated when the lift speed reached 1.37m/s and triggered the operation of the safety gears. With the design operating conditions exceeded due to overloading, although the brake and safety gears had reduced the downward speed of the lift car, the lift continued to slip downward and was finally stopped after hitting the buffer at the bottom of the lift pit.

7. Measures to Step up Regulatory Control on Lift Safety

7.1 Subsequent to the lift incident, EMSD had taken immediate actions to inspect the other two lifts installed at the same building to ensure the safe working order of these lifts.

7.2 To enhance public awareness of the safe use of lifts and the proper way to prevent overloading of lifts, a new Announcement of Public Interest entitled “Don’t Overload Lifts” has been broadcast on TV channels since 18 November 2014, and has been uploaded to the EMSD YouTube Channel as well as Information Services Department media channels. Copies of a new poster on “Don’t Overload Lifts” (“防止升降機超載”) have also been distributed to promote the safe use of lifts. Letters are also being sent to relevant Responsible Persons to remind them of the importance to properly manage their lifts against overloading.

7.3 To facilitate Responsible Persons to better understand their duties and responsibilities under the Ordinance, EMSD has stepped up publicity and public education by arranging more seminars for Responsible Persons to enhance their knowledge of daily management of lifts and regarding entering into maintenance contracts with registered lift contractors.

7.4 A circular letter has been issued to remind the trade about the importance of proper maintenance of lift brakes, governors, governor rope systems and safety gears. According to Section 16 of the Lifts and Escalators Ordinance (Cap 618), registered lift contractors who undertake any lift works must ensure that the works are carried out properly and safely. They are also required to ensure that the lift and all its associated equipment or machinery are kept in a proper state of repair and in safe working order.

7.5 EMSD has stepped up surprise checks on the condition of governor systems and lift brake systems to ensure that they are properly maintained.

Appendix

Basic Structure of Lift

The basic structure of a lift consists of a vertical lift well in which the lift car is placed. Guide rails are installed inside the lift well, which restrict the lift car to move up and down in a controlled manner.

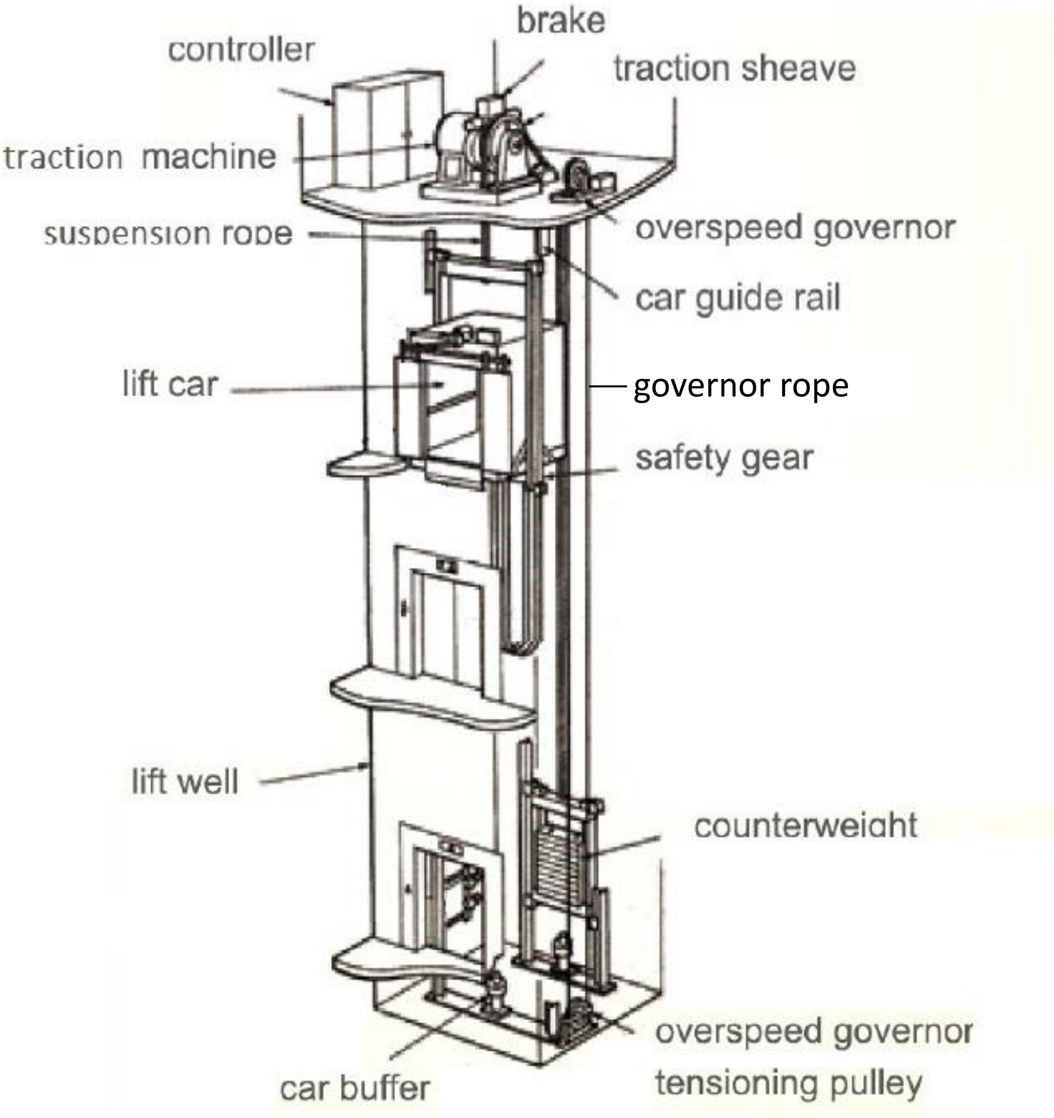
Multiple steel ropes (suspension ropes) are used to move the lift car, which are driven by the traction machine installed inside the machine room, usually located on the roof level. One end of these suspension ropes is connected to the lift car and the other end is connected to the counterweight for balancing. When the lift car moves, the counterweight will move in the opposite direction. The traction machine is fitted with a traction sheave, over which suspension ropes are laid. The suspension ropes are in contact with the grooves of the sheave and driven by means of friction between the contact surfaces. The suspension ropes and traction sheave are subject to wear and tear during lift operation, and have to be checked and replaced regularly.

The suspension ropes shall have a tensile grade corresponding to those specified in ISO 4344 or other relevant international standard. The safety factor (ratio between minimum breaking load and the maximum force in the rope) of the suspension rope shall be at least 12.

In spite of the high safety factors, suspension ropes should be replaced immediately when the rope has worn down by more than 10% of its diameter or the number of wire breaks is excessive in order to keep the lift in safe working order.

The traction machine is used to drive the traction sheave so as to raise or lower the lift car via suspension ropes. Traction lifts have a number of safety devices to maintain the lift car in a safe position in the event of equipment failure. Basic safety components include overspeed governor, safety gears in the car, counterweight (if applicable) and buffer at the bottom of lift shaft. In case the lift car travels at a speed higher than the design speed due to failure of the suspension system, the overspeed governor will be activated which will in turn activate the safety gears for clamping onto the guide rails to stop the lift car and the counterweight and hold them in a safe position.

At the bottom of the lift well, a buffer is usually installed to damp down the final movement of the lift car. The above-mentioned safety components are detailed below:



Major Safety Components of the lift

1. Overspeed Governor

The overspeed governor is essentially made of two pulleys connected to each other by a small rope located inside the lift shaft. The rope ends are connected to the safety gears located below the lift car. When the downward speed of the lift car reached the predetermined value (the tripping speed), the overspeed governor would be activated to cut the power supply to the drive machine and to activate the safety gears to stop the lift car from further overspeeding or falling.

Figure A shows the typical arrangement of the overspeed governor system of the lift. The governor is located inside the lift machine room / inside the lift shaft. It is provided with a governor rope passing round the governor sheave down to a tensioning pulley in the pit and back again to the governor sheave. The system is driven by the lift car to which the governor rope is attached at point.

The tensioning pulley is located at the low level of the lift shaft. It is used to maintain and monitor the tension of the governor rope. The tensioning weight should, throughout the lift machine operation, maintain at the normal position (3 o'clock) in order to ensure proper tension could be maintained in the governor system. The position of the tensioning weight should also be monitored by a governor rope slack switch in which any breakage or slackening of the governor rope should trigger the switch to cause the control power of the lift to switch off immediately.

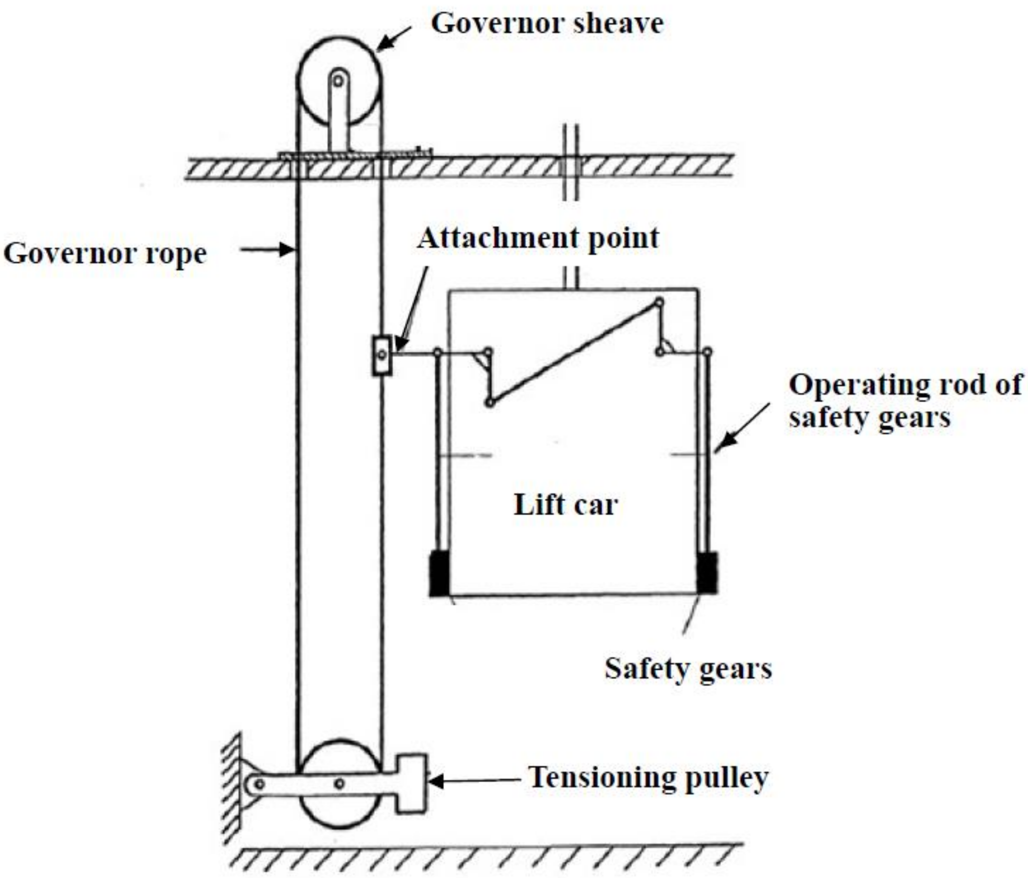


Figure A : Typical arrangement of overspeed governor system of lift

2. Safety Gears

Figure B shows the typical arrangement of the supporting frame of the lift car. The pair of safety gears (9) is mounted at the bottom of the supporting frame. When the governor rope (1) is gripped by the shoe of the overspeed governor, any further downward movement of the lift car will rotate the lever arm (2) on the pivoted point (3) and actuate a mechanism to operate the safety gears to clamp onto the guide rails. Linkage rod (10) ensures simultaneous operations of the safety gears. The design of the safety gears system for the lift involved in the incident was slightly different from that shown in Figure B in that the lever arms and linkage rod were mounted at the bottom of the supporting frame. Figure C shows the drawing of the bottom frame and safety gears of the lift involved in the incident. Figure D shows the design of safety gears similar to the one involved in the incident. The assembly comprises two wedge-shaped gibs (1) moving on metal rollers (2) mounted in a casing (3) and running in the track of the jaw (4).

When the safety gears are activated by the overspeed governor, the gibs are raised and brought into contact with the guide rail. Downward movement of the lift car is counteracted by the wedging action of the gibs on the guide rail.

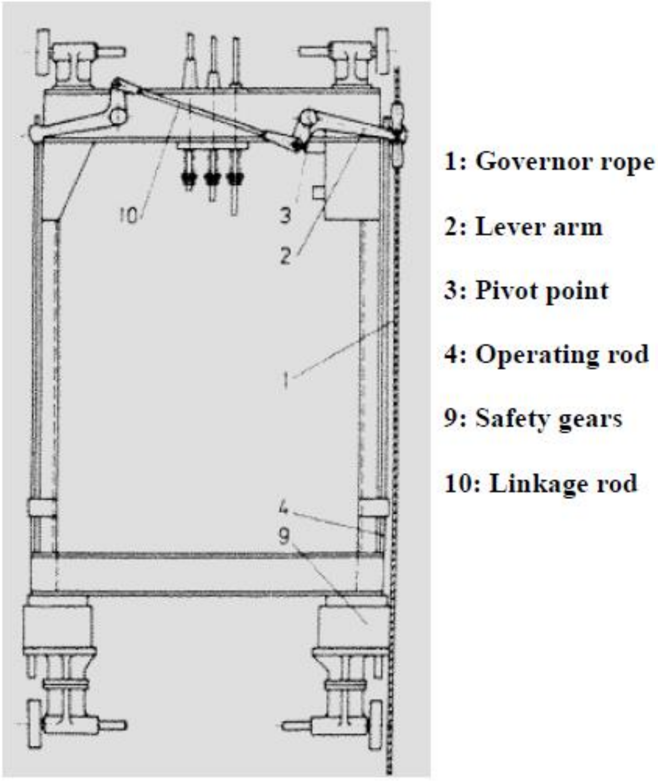


Figure B : Typical arrangement of lift car frame

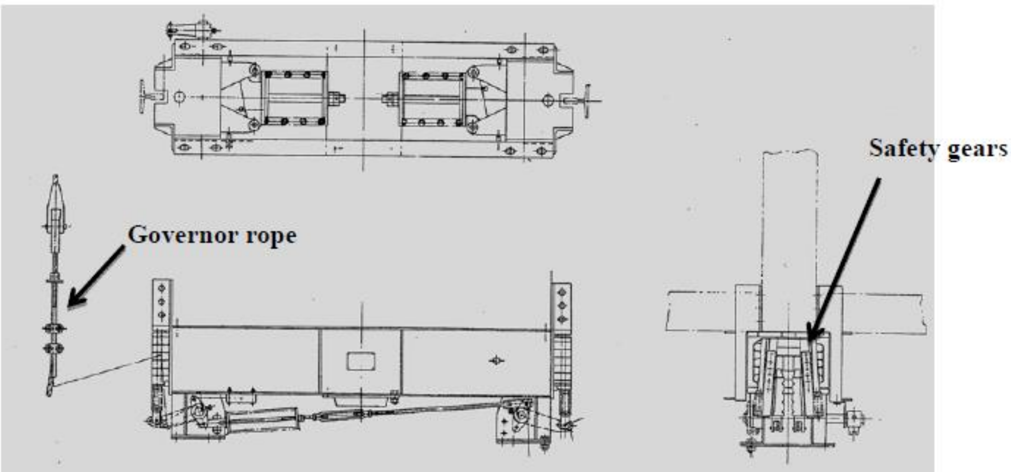


Figure C : Drawings for the bottom frame and safety gears of lift No. 1

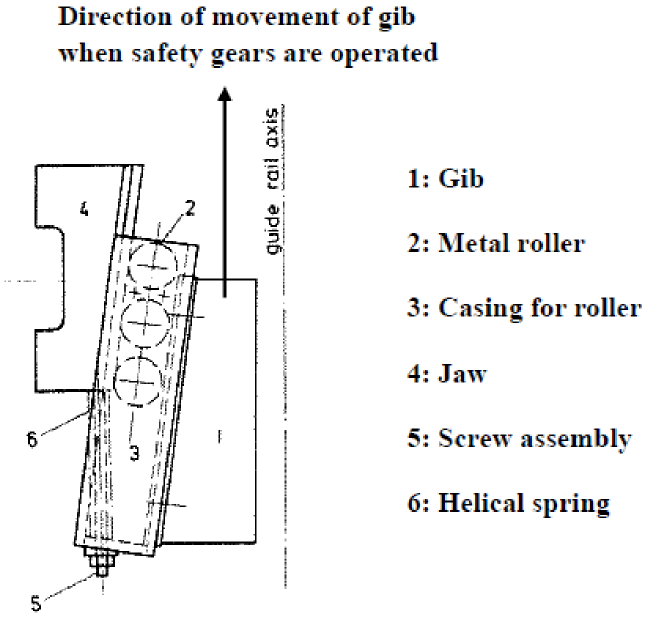


Figure D : Safety Gears design

3. Buffer

A lift must be equipped with buffers located at the bottom limit of travel for both cars and counterweights to constitute the final emergency device. The buffers absorb the energy of impact of the lift car/counterweight overspeeding downwards but at a speed lower than the activation speed of the safety gears. Helical spring buffers of round section are installed at the lift pit for the car and counterweight of the lift involved in the incident. This type of buffer is called energy accumulation type buffer which may be used for a lift with rated speed not exceeding 1 m/s. For lift with rated speed above 1 m/s, buffer of energy dissipation type (oil buffer) must be used. Figure E shows a spring buffer used for the lift.

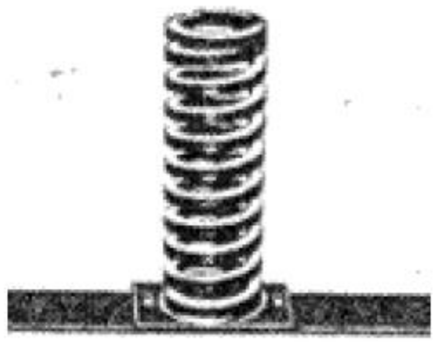


Figure E : Spring buffer of lift