Technical Investigation Report on Escalator Incident at Langham Place, Mong Kok, Kowloon

九龍旺角朗豪坊自動梯事故技術調查報告

Date of Incident: 25 March 2017
事故日期：2017 年 3 月 25 日

English Version
英文版

機電工程署 EMSD

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Executive Summary

At about 4:30 pm on 25 March 2017, Otis Escalator No. E18 installed at Langham Place, 8 Argyle Street, Mong Kok, Kowloon, which was conveying around 120 passengers upwards from 4/F to 8/F, suddenly stopped and reversed its operation direction, causing injuries to 18 passengers. Among them, three were hospitalised.

The investigation team of the Electrical and Mechanical Services Department (EMSD) promptly attended the scene for on-site investigation. The investigation revealed that the main drive chain was broken. The broken chain safety device (BCD) installed for monitoring breakage and excessive elongation of the main drive chain had not been triggered to activate the auxiliary brake to stop the escalator operation. Since the escalator had lost its upward traction power, it reversed downwards due to the weight of passengers. The incident was caused by the double failure of the main drive chain and BCD. There was no overloading of the escalator.

Laboratory analysis of the failed main drive chain revealed that the breakage was caused by metal fatigue. For the BCD, sticky grease, which was formed from lubrication oil for the main drive chain and dust in the surrounding environment, was found on its moving parts. Also, one of the two springs designed to push the moving mechanism of the BCD had been locked and made ineffective prior to the incident. Consequently, the BCD did not function properly to activate the auxiliary brake.

The EMSD attaches great importance to escalator safety. Following the incident, special inspections were conducted to all high rise escalators with vertical rise equal to or exceeding 15 metres and all Otis escalators to ensure public safety. Also, the EMSD has issued a reminder to registered escalator contractors and registered escalator engineers on proper maintenance and examination of main drive chain and BCD according to the Code of Practice for Lift Works and Escalator Works. In addition, responsible persons and registered escalator contractors of high rise escalators are reminded to allocate adequate resources and time to closely monitor and maintain such escalators respectively. The EMSD has also stepped up the sampling inspections to such escalators.

Technical Investigation Report on Escalator Incident
at Langham Place, Mong Kok, Kowloon on 25 March 2017

1. Objectives

1.1 The purpose of the technical investigation is to identify the causes of the escalator incident occurred at Langham Place, Mong Kok, Kowloon on 25 March 2017. This report presents the results of the technical investigation into the incident by the Electrical and Mechanical Services Department (EMSD).

2. Background of the Incident

2.1 The escalator incident occurred at Langham Place, Mong Kok at around 4:30 pm on 25 March 2017. At the time of the incident, the upward moving Escalator No. E18 linking 4/F and 8/F with a vertical rise of 21 metres stopped suddenly and moved downwards. Many passengers on the escalator lost balance and 18 of them suffered injuries. Among the injured passengers, three were hospitalised and the remaining ones were discharged after treatment at the hospital.

3. Technical Information of the Escalator Involved in the Incident

3.1 The escalator was driven by two traction machines with two alternating current (AC) three-phase induction motors. Mechanical power from the traction machine sprocket is transferred to the step side sprocket via the main drive chain. For the basic structure of an escalator, please refer to Appendix 1. For illustration of the drive system, please refer to Figures 1a and 1b.

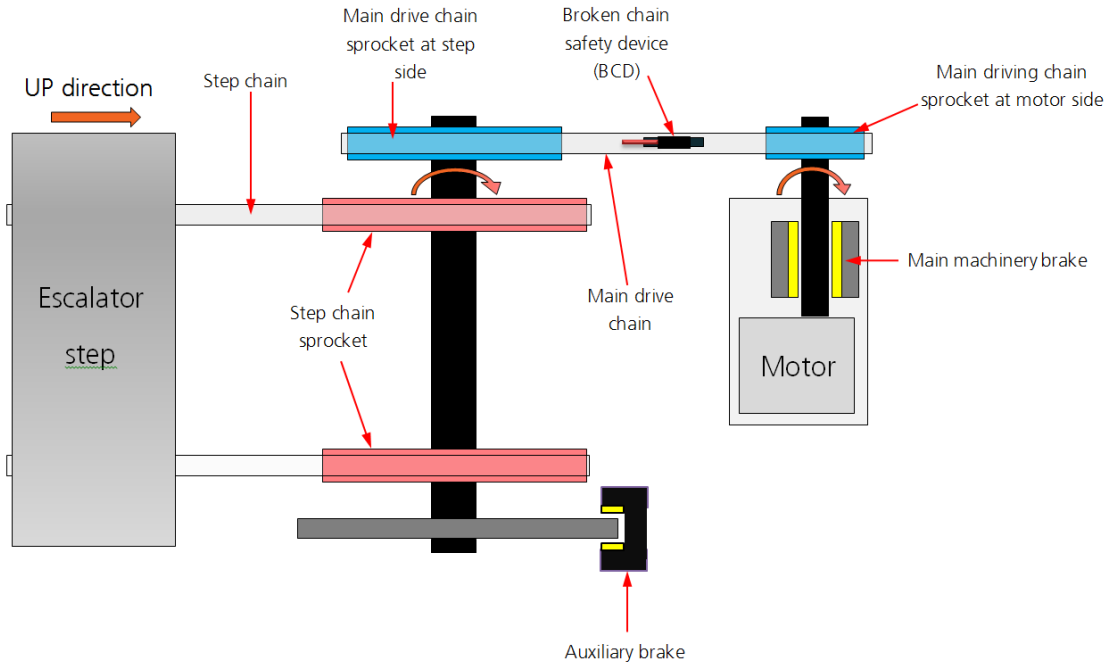

Figure 1a: Schematic diagram of an escalator drive system

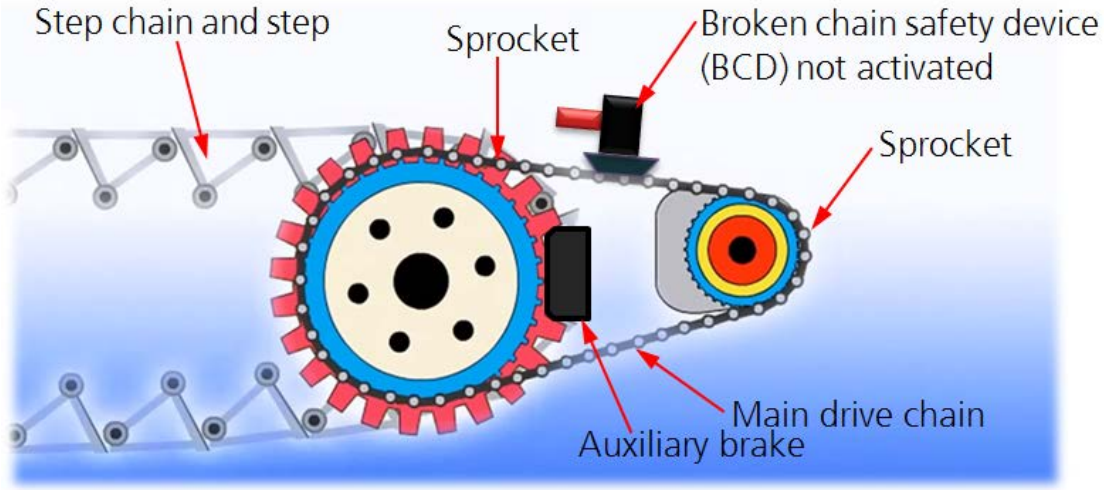

Figure 1b: Sectional view of an escalator drive system under normal operation

3.2 Technical details of the escalator are summarised as follows:

Make and Model	:	OTIS/520 NPE
Country of Principal Manufacturer	:	Germany
Driving Motor	:	AC three-phase Induction Motor
Rated Speed	:	0.5 metre per second
Step Width	:	1 metre
Rise	:	21 metres
Angle of Inclination	:	30^{o}
Floors Served	:	Between 4/F and 8/F

Year of Installation	:	2004
Registered Escalator Contractor for Maintenance of the escalator	:	Otis Elevator Company (HK) Ltd.
Date of Last Examination by Registered Escalator Engineer prior to the Escalator Incident	:	24 January 2017
Date of Last Routine Maintenance entered in logbook by Registered Escalator Worker prior to the Escalator Incident	:	23 March 2017

4. Approach of Investigation

4.1 In carrying out the investigation of this incident, the EMSD has

(i) checked the logbook of the escalator involved (i.e. Escalator No. E18);
(ii) reviewed the CCTV footage of past two months of the escalator involved;
(iii) taken witness and cautioned statements from relevant personnel, including registered escalator workers, registered escalator engineer, registered escalator contractor, and the property management of Langham Place (i.e. The Great Eagle Properties Management Co. Ltd.);
(iv) obtained relevant documents such as maintenance records/maintenance manual from the registered escalator contractor for detailed checking;
(v) obtained technical information of the main drive chain from both Otis and the original chain manufacturer; and
(vi) appointed four independent experts to provide professional advice on the cause of the escalator incident, and various aspects on the maintenance and design of the escalator involved, as well as conducting stereo micrography and scanning electron micrography of the failed items.

5. Site Investigation Findings

5.1 The investigation findings revealed that the main drive chain of the escalator was broken at the time of the incident. As a result, the escalator, originally running upwards before the incident, lost the driving power, slowed down and finally moved in reverse direction (i.e. downward direction) due to the weight of the passengers and escalator steps.

5.2 Under normal circumstance, the breakage and/or excessive elongation of the main drive chain are continuously monitored by the broken chain safety device (BCD, Figures 1 and 3 refer). In case of breakage or excessive elongation of the main drive chain, the BCD will be triggered and will send a signal to activate the auxiliary brake to stop the moving escalator (Figure 2a refers). In this incident, upon breakage of the main drive chain, the BCD failed to detect the chain breakage and the auxiliary brake was not activated to stop the moving escalator (Figure 2b refers).

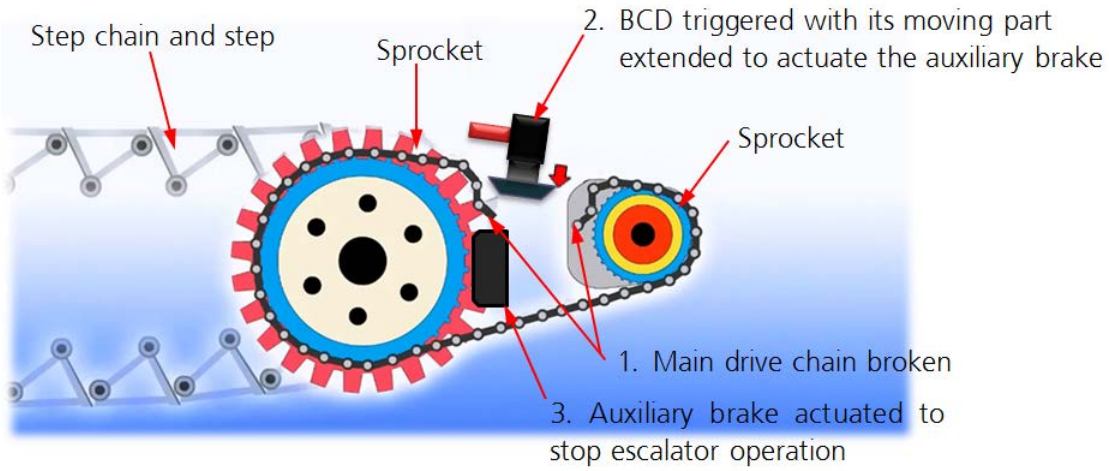

Figure 2a: Design to protect against main drive chain failure

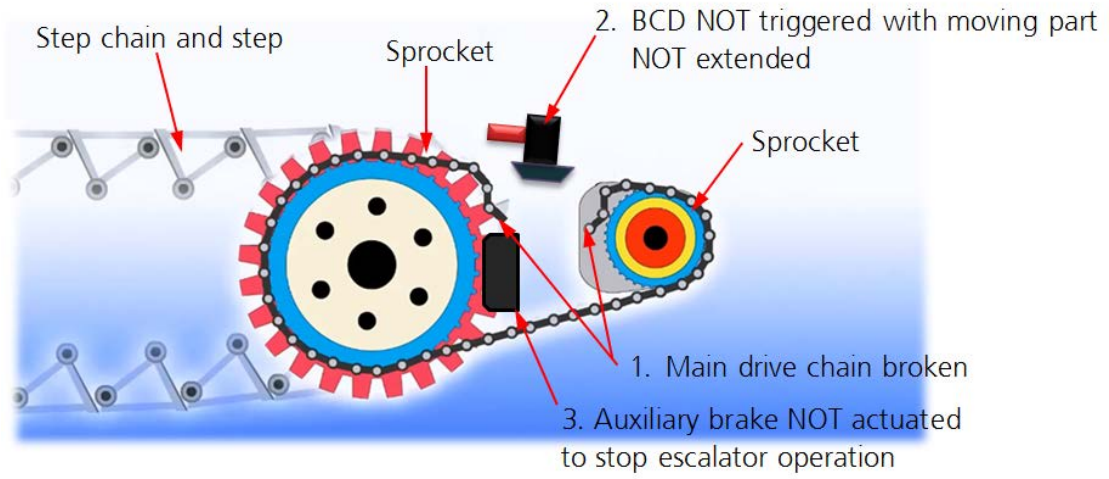

Figure 2b: Double failure of the main drive chain and BCD in the incident

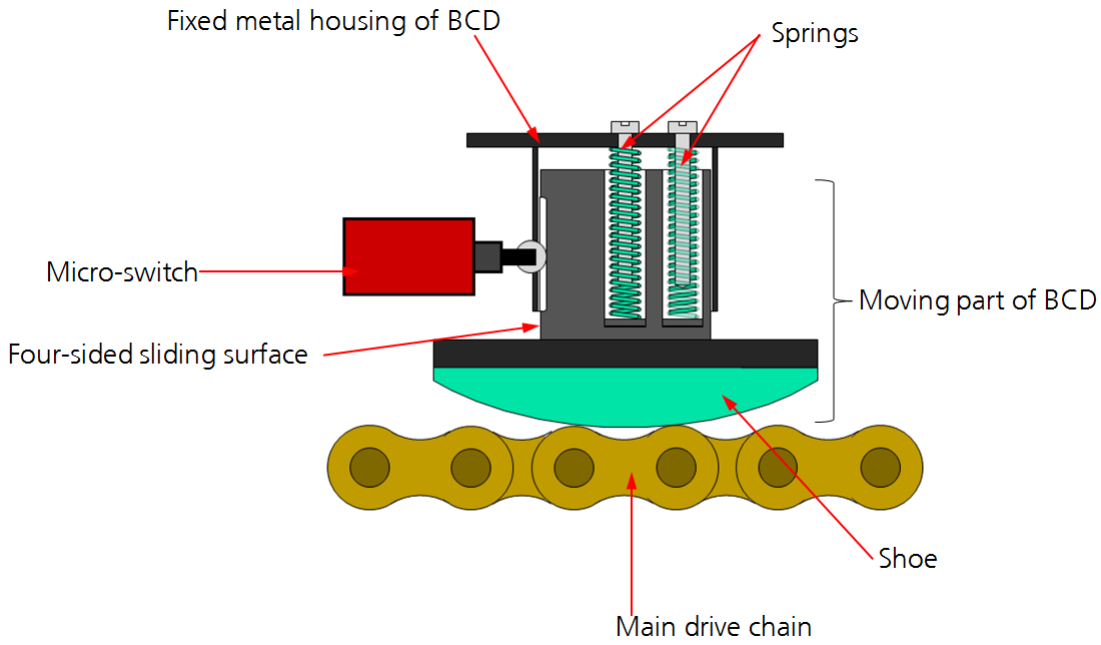

Figure 3: Construction of BCD

5.3 The incident was caused by the double failure of both the main drive chain and BCD. Such double failure is very rare. According to the EMSD's records, there was no similar failure occurred in Hong Kong previously.

5.4 The CCTV footage of the incident was examined. It was confirmed that there was no overloading of the escalator.

6. Investigation Findings by Material Experts

6.1 To identify the root cause of main drive chain and BCD failures, the EMSD carried out analysis and diagnosis together with material experts.

6.2 Failure Analysis of Main Drive Chain

6.2.1 The main drive chain is a steel triplex roller chain. The chain model is G0332P30. It consists of 104 pins. This chain serves to transmit mechanical power from the traction motors to the step chain.

6.2.2 In order to identify the exact elements of the chain during examination, each of the 104 pins were uniquely numbered after the incident for detailed analysis.

6.2.3 After the incident, the main drive chain was found broken. According to the numbering system, the breakage occurred between pin Nos. 1 and 104. Figure 4 shows the breakage position of the main drive chain right after the incident.

Figure 4: Photo showing the breakage position of main drive chain

6.2.4 The breakage of the main drive chain was further analysed by material experts at laboratory by stereo micrography and scanning electron micrography. All fracture surfaces contain beach marks, which are characteristics of metal fatigue. (Figures 5 and 6)

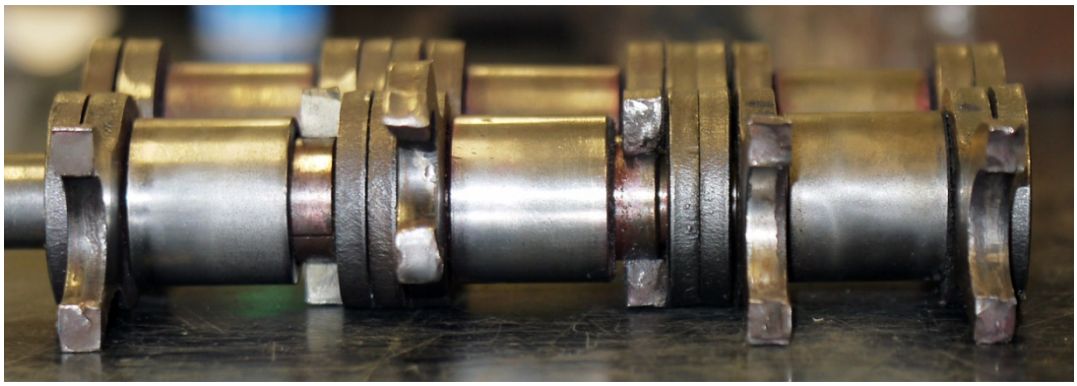

Figure 5: Broken roller link plates

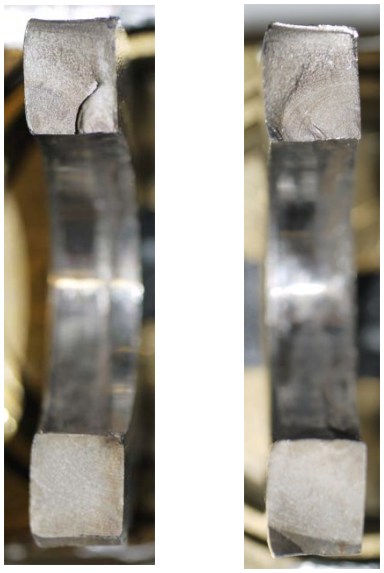

Figure 6: Fracture surfaces

6.2.5 Other than the chain breakage position in between pin Nos. 1 and 104, link plates were also found broken/cracked at other pins (Figure 7).

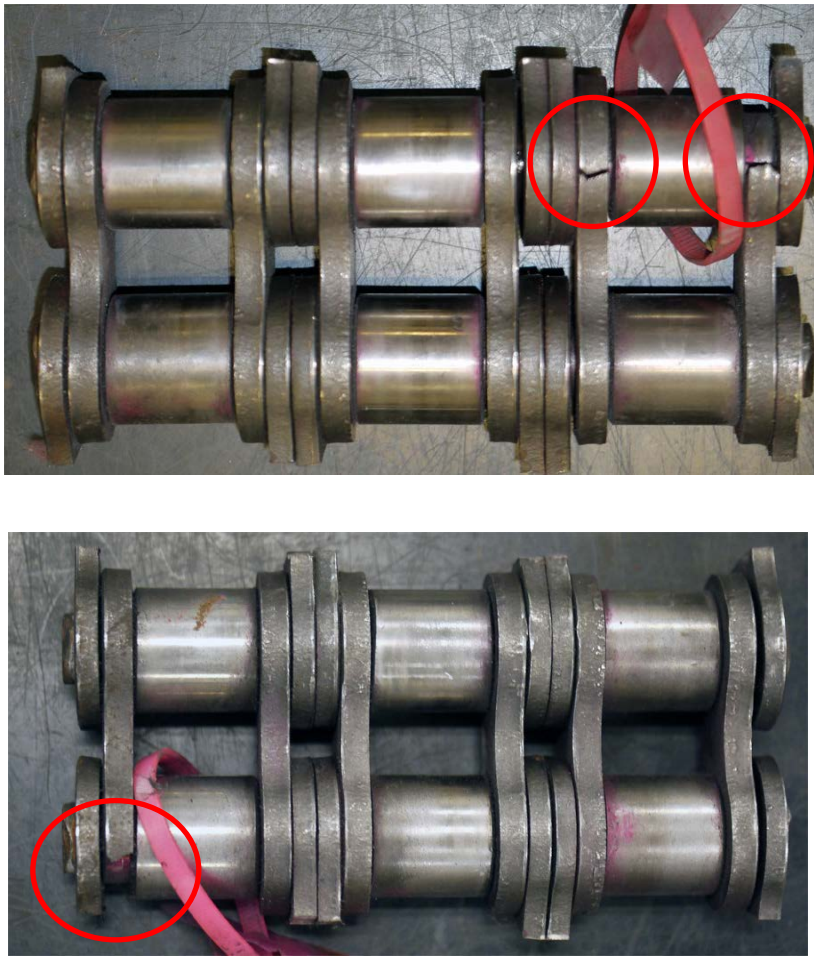

Figure 7: Other broken/cracked roller link plates

6.2.6 Apart from the abnormal damage to the main drive chain, abnormal wear and scratch were also found at the teeth of the motor sprocket and the step chain sprocket. Figure 8 shows the wear surface on the teeth of motor sprocket.

Figure 8: Photo of wear surface on the teeth of motor sprocket

6.3 Failure Analysis of Broken Chain Safety Device

6.3.1 According to the Code of Practice on the Design and Construction of Lifts and Escalators, a safety device (the BCD in this case) should be provided which shall trigger the brake to stop the escalator and maintain it stationary in case of breakage or undue elongation of the main drive chain. Also, in the event of failure of the coupling of the operational brake and the driving wheels of the steps (i.e. main drive chain in this case), the auxiliary brake should become effective.

6.3.2 As shown in Figure 3, the BCD moving part is installed within the fixed metal housing. At the bottom of the moving part, there is a plastic shoe. The moving part is designed to move freely up and down within the fixed metal housing. There are two compression springs installed at the fixed metal housing. Under normal circumstances, the two compression springs press the moving part and the plastic shoe so that the shoe is in contact with and is sliding on the moving main drive chain during escalator operation. When the main drive chain is broken or has excessive elongation, the compression springs will push the moving part and the shoe downwards. There is a micro-switch fixed at the BCD housing. When the moving part is pushed downwards, the curvature at the sliding surface of the moving part will trigger the micro-switch. The micro-switch will then provide a signal to activate the auxiliary brake.

6.3.3 After the incident, the BCD as shown in Figure 9 was seized for laboratory investigation. Having disassembled the BCD, sticky grease was found between the fixed metal housing and the sliding surface of the moving part. The sticky grease was formed from the mixture of oil used for lubricating the main drive chain and dust from the environment.

Figure 9: Photo of the BCD moving part and the shoe. Mixture of lubrication oil and dust formed the sticky grease, which was found on the surface.

6.3.4 Furthermore, it was found that one of the two compression springs had been locked and made ineffective (i.e. not providing spring force to the BCD moving part), thereby causing reduced spring force to push the moving part downwards. Please refer to Figure 10 for illustration.

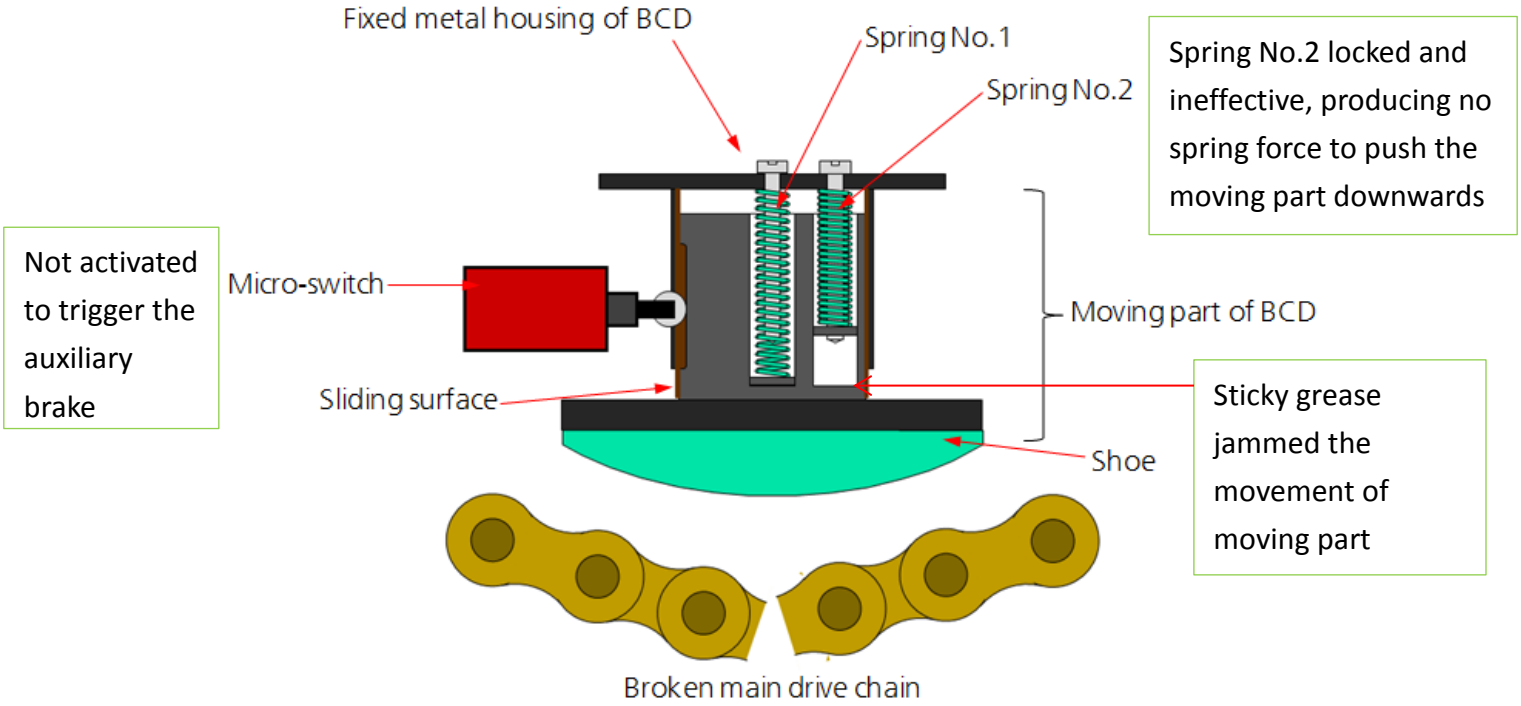

Figure 10: Illustration of BCD with spring No. 2 locked and made ineffective

6.3.5 The increased friction between the moving part and the fixed metal housing arisen from the sticky grease and the reduced spring force due to an ineffective spring had resulted to the non-operation of the BCD, so that the moving part and the shoe were not extended downwards to activate the micro-switch when the main drive chain was broken. The auxiliary brake was therefore not activated to stop the escalator.

6.3.6 When the escalator was speeding up downwards and moving unintentionally in the reverse direction, relevant protections had been triggered to actuate the main machinery brake. However, since the main drive chain had been broken, operation of the main machinery brake could not stop the downward moving escalator. The downward movement was finally stopped when some passengers had left the escalator steps.

7. Conclusions

7.1 This escalator incident was due to breakage of main drive chain and malfunction of the BCD.

7.2 The breakage of the main drive chain was due to metal fatigue. The malfunction of BCD was due to sticky grease on the sliding surface of the moving part of the BCD and improper setting of the compression springs. The sticky grease and the reduced spring force had hindered the operation of the moving part so that no signal was sent to the auxiliary brake to stop the escalator when the main drive chain was broken.

7.3 According to the Code of Practice for Lift Works and Escalator Works, the main drive chain should be inspected for any sign of wear and tear and the BCD should be properly maintained, checked, adjusted and tested during periodic maintenance and periodic examination.

8. Measures Taken after the Incident

8.1 In order to ensure passenger safety, the EMSD prohibited the operation of the incident escalator and other three high rise escalators at Langham Place after the incident. Otis had then replaced the main drive chain and the BCD of the other three escalators. Also, the escalators were thoroughly examined by the registered escalator engineer concerned. Except the incident escalator No. E18, the other three high rise escalators in Langham Place have resumed normal operation.

8.2 The EMSD had accorded 30 performance monitoring points to Otis for the breakage of the main drive chain and malfunctioning of the BCD in the Langham Place escalator incident and issued a warning letter to Otis for its poor performance. The Safety Star and all Quality Stars were removed from Otis in the Contractors' Performance Ratings of Registered Escalator Contractors at the first quarter of 2017 (i.e. January to March 2017) announced on 10 April 2017. The EMSD continues with the criminal investigation into the cases and prosecution/disciplinary actions against the registered escalator contractor, registered escalator engineers and/or registered escalator workers concerned will be considered if non-compliance with the Lift and Escalator Ordinance, Cap. 618, is found in the investigation.

8.3 There are 64 high rise escalators with vertical rise exceeding 15 metres in Hong Kong, including the four at Langham Place, as at March 2017. Due to their high patronage, the EMSD considered it prudent to reconfirm the safety of these escalators and assure the public of their safety through a special inspection by the respective registered escalator contractors after the incident. The inspections were completed within a week of the incident on 31 March 2017. No abnormality was found and all escalators were confirmed to be in safe working conditions. The EMSD also requested Otis to conduct special inspections of all Otis escalators in Hong Kong within a month from 3 April 2017. The EMSD scrutinised Otis's inspection plan and conducted sampling checks on site. The main drive chain of one Otis escalator was found having excessive elongation exceeding 2% and has subsequently been replaced before resuming operation.

8.4 In April 2017, the EMSD also randomly selected escalators from other registered escalator contractors under their maintenance for special inspections. No abnormality was found during our special inspections.

8.5 The EMSD issued a reminder circular No. 3/2017 on 7 April 2017 to remind all registered escalator contractors and registered escalator engineers that the BCD should be properly maintained to ensure the free operation of its entire activation mechanism and to be fully tested to check the full integrated operation of its electrical and mechanical components. Also, the main drive chain should be closely inspected to confirm that it is free from cracks, breakage and excessive elongation, all in accordance with the relevant clauses in the Code of Practice for Lift Works and Escalator Works.

8.6 The EMSD has also issued a letter to the responsible persons (RPs) and registered escalator contractors of high rise escalators to provide guidelines on maintenance of these escalators. The RPs are reminded to allow sufficient time for their registered escalator contractors to complete the periodic maintenance works in each routine maintenance. They should request their contractors to provide a maintenance schedule on periodic maintenance, and closely monitor their work to ensure that the periodic maintenance works are carried out in accordance with the Code of Practice for Lift Works and Escalator Works and maintenance schedule. In view of the high passenger carrying capacities of high rise escalators and thus the more serious consequences to passengers if an escalator incident occurs, the EMSD has carried out more inspections to such escalators.

8.7 In accordance with the Lift and Escalator Ordinance, Cap. 618, RPs must ensure that the lifts and escalators and all their associated equipment or machinery are kept in a proper state of repair and in safe working order. The EMSD has published the Guidebook for Responsible Persons for Escalators to provide guidance to RPs on how to effectively keep their escalators in a proper state of repair and in safe working order. The EMSD will further publicise the role and responsibility of RPs, including RP’s role to closely monitor and check the performance of registered contractors, examine and countersign maintenance logbooks, regularly inspect the operation of escalator and manage the proper operation of escalator, etc. It is the joint effort of the registered contractors, registered engineers, registered workers, responsible persons and the Government to ensure the sustained safety of escalator operation.

~End of Report~

Appendix I – Basic Structure of Escalator