Technical Investigation Report on
Lift Incident at Paris Court,
Sheung Shui Town Centre, New Territories

新界上水名都巴黎閣
升降機事故
技術調查報告

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事故日期：2018 年 5 月 11 日

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機電工程署 EMSD

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Executive Summary

At 12:46 pm on 11 May 2018, Lift No. 5 installed at Paris Court, Sheung Shui Town Centre, 9 Chi Cheong Road, Sheung Shui, New Territories moved upwards unintentionally from 7/F while its doors were opened, causing the death of a woman aged 64.

The investigation team of the Electrical and Mechanical Services Department (EMSD) promptly attended the scene for on-site investigation. All safety switches and control circuitries were in normal conditions. However, the lift brake plungers were found not lubricated for a long time and could not be operated smoothly occasionally. As a result, the brake linings continuously rubbed against the brake drum during the operation of the lift, thereby overheating the brake linings and significantly reducing the braking force. In addition, due to the vibration arising from the rubbing, a fixing screw in a brake lining had loosened and protruded out from the lining surface, so that the contact surface area between the brake lining and the brake drum was reduced to further lower the braking force. The total braking force became insufficient to brake the moving lift car.

When the lift car reached 7/F from G/F to answer a call, its doors were opened and the victim entered the lift. However, due to insufficient braking force, the lift car had not been completely stopped and continued to move upward. The victim tried to enter the lift car but was trapped in between the landing lintel and the lift car door sill. She struck to escape from trapping but eventually fell down to the bottom of the lift pit and died.

The EMSD attaches great importance to lift safety. Following the incident, to ensure public safety, special inspections were conducted to all “Guangri” brand lifts by various registered lift contractors maintaining such lifts, as well as to all the lifts of different brands being maintained by the registered lift contractor of the Incident Lift. No abnormality was found. The EMSD has also stepped up the sampling inspections to such lifts. Furthermore, the EMSD has issued Circular No. 6/2018 dated 9 July 2018 to remind all registered lift contractors to properly carry out brake system overhauls according to the manufacturers’ recommendations.

Technical Investigation Report on
Lift Incident at Paris Court, Sheung Shui Town Centre, New Territories on 11 May 2018

1. Objectives

1.1 The purpose of the technical investigation is to identify the causes of the lift incident which occurred at Lift No. 5 at Paris Court, Sheung Shui Town Centre, New Territories (the "Incident Lift") on 11 May 2018. This report presents the results of the in-depth technical investigation into the incident by the EMSD.

2. Background of the Incident

2.1 The lift incident occurred at the Incident Lift at 12:46 pm on 11 May 2018. During the incident, the empty Incident Lift car was at G/F and received a landing call from 7/F. The Incident Lift car then moved to 7/F. Although the motor drive had already been stopped, the lift car had not been completely stopped when the lift car door was opened. While a woman aged 64 (the victim) was entering the lift car at 7/F, the car continued to move upwards with the lift car door and landing door both still opened. The doors started to close after the lift car raised to the upper door open limit position of 7/F and trapped the victim. The victim tried to enter the lift car but was trapped in between the landing lintel and the lift car door sill. She struck to escape from trapping but eventually fell down to the bottom of the lift pit and died. The lift finally stopped at around 12/F.

3. Technical Information of the Lift Involved in the Incident

3.1 Table 1 shows the specifications of the Incident Lift. For the basic structure of an electric traction lift, please refer to Appendix I.

Lift No.	5
Lift Type	Electric Traction Passenger Lift
Manufacturer	Guangzhou Guangri Elevator Industry Co., Ltd. (commonly known as "Guangri" brand)
Country of Origin	China
Rated Capacity	1 000 kg
Rated Speed	1.75 m/s
Gearbox	Worm gear
Roping	1:1

Electric Motor	Three-phase alternating current (AC) induction motor
Brake System	Drum brake with single compression spring
Suspension Rope Nominal Diameter	12 mm
Number of Suspension Ropes	5
Floor Served	G/F, 1/F, 3/F, 5/F, 7/F, 9/F, 11/F, 13/F, 15/F, 17/F, 19/F, 21/F, 23/F and 25/F
Registered Lift Contractor for Maintenance of the Lift	Eugene Engineering Co. Ltd. (Registered Lift Contractor No. RLC03002)
Date of Last Examination by Registered Lift Engineer Prior to the Lift Incident	2 March 2018
Date of Last Routine Maintenance Entered into Logbook by Registered Lift Worker Prior to the Lift Incident	9 May 2018

Table 1

3.2 The construction and operation of the electromechanical brake system of the Incident Lift are illustrated in Figures 1 to 4 below:

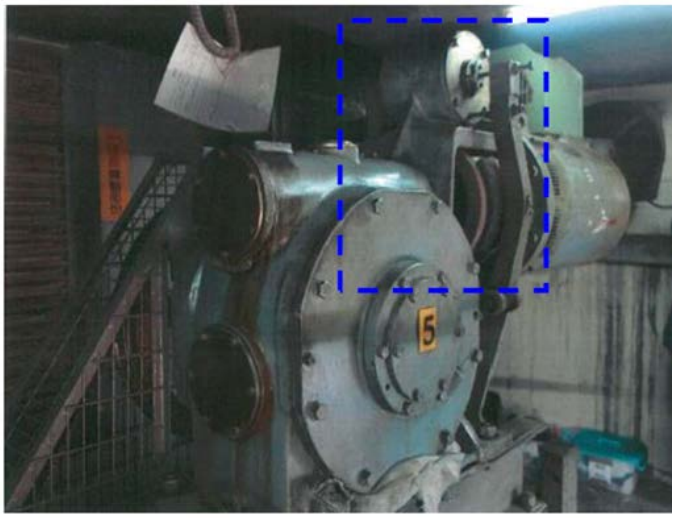


Figure 1: Photo of lift traction machine

(Electromechanical brake system highlighted by blue dotted lines)

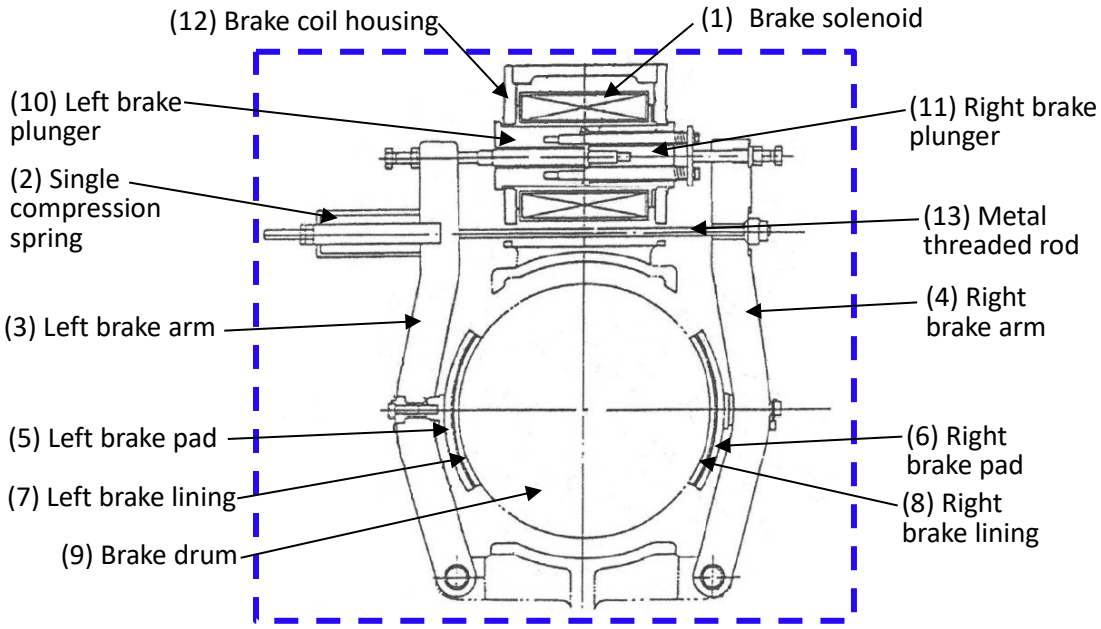


Figure 2: Construction and operation of electromechanical brake

To stop a lift, electricity supply to the brake solenoid (1) should be cut off and hence no magnetic field is generated. The single compression spring (2) will then push the left brake arm (3) to the right and pull the right brake arm (4) to the left through a metal threaded rod (13). The left and right brake pads (5 and 6) comprising left and right brake linings (7 and 8) respectively will press on the brake drum (9), which is a mechanical component axially connected to the lift motor, to stop the lift car movement (Figure 3).

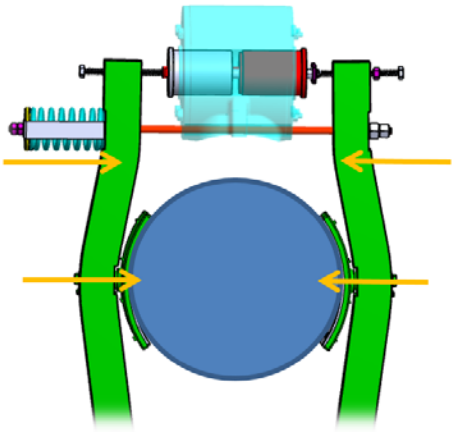


Figure 3: Brake Closed

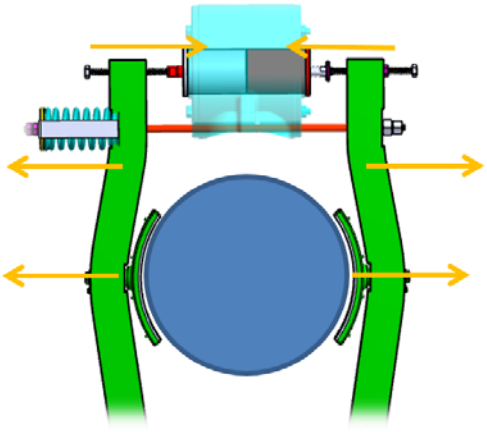


Figure 4: Brake Opened

When the lift is called to run, the lift control panel will energise the brake solenoid (1) electrically, thereby providing magnetic field inside the brake coil housing (12). The left and right brake plungers (10 and 11) inside the brake coil housing (12) will be magnetised and move towards each other. The brake arms (3 and 4) and the associated brake pads (5 and 6) attached to the brake arms will move away from the brake drum (9). The brake is disengaged and the lift motor can rotate freely. The lift motor will then be energised electrically by the lift control panel to move up or down according to the lift operation (Figure 4).

4. Approach of Investigation

4.1 In conducting the investigation into this incident jointly with the Police, the EMSD has carried out the following:

a) checked the logbook of the Incident Lift;
b) reviewed over 12 hours of the CCTV footage covering the Incident Lift of the day before and when the incident happened;
c) interviewed 25 people and taken statements from relevant personnel, including residents of Paris Court, staff of the property management company, registered lift workers, registered lift engineer, registered lift contractor, and the principal manufacturer (i.e. Guangzhou Guangri Elevator Industry Co., Ltd.);
d) reviewed over 200 documents involving 20 different categories; and
e) appointed four independent experts to conduct on-site simulation tests and various laboratory tests on the brake linings, brake coil, brake plungers and its associated components in order to provide professional advice on the causes of the lift incident.

5. Technical Investigation Findings

The EMSD investigation team attended the site immediately once notified of the incident on 11 May 2018. Preliminary tests were conducted on site. All safety switches and control circuitries were found in normal conditions. All the suspension ropes were intact. After this, the EMSD promptly engaged four independent experts to join the investigation team. The following facts were found:-

5.1 Investigation Findings by Lift Expert

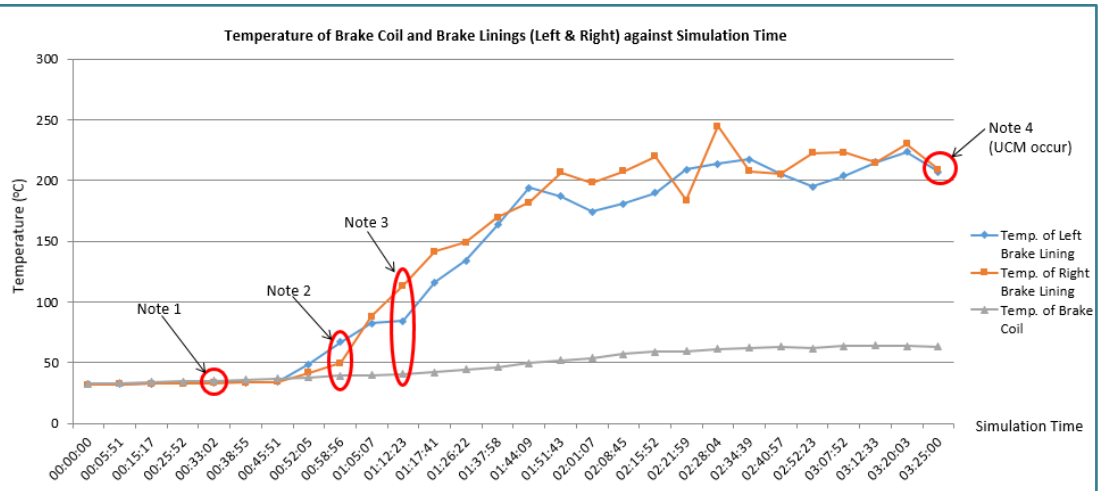
a) All safety switches of the Incident Lift were inspected, tested and examined, and were found functioning properly.

b) As observed from the CCTV footage, the Incident Lift had moved upwards unintentionally for four times during the morning before the incident took place. There was no injury and no abnormal operation report received by the management company.

c) The brake did not stop the lift car of the Incident Lift at 7/F when the victim was entering the lift at the time of the incident, but finally stopped it at around 12/F.

d) The travel pattern of the lift before the time of the incident was recorded in order to simulate the complete sequence of event. A thermal imager (Figure 5) was used to record the temperature of the brake coil and the brake linings. The simulation results are shown in Figure 6. The simulation test was started at 00:00:00 (hh:mm:ss). With the lift operated as per the pattern before the incident, it was found that at the simulation time of 00:33:02, the left and right brake plungers started to operate asynchronously and sluggishly (with around 1 second delay between their movements). The simulation test continued and it was found that the brake plungers started to stop moving, causing the brake arms and associated brake linings unable to open at simulation time 01:12:23. With the brake plungers failed to move, the brake linings (both left and right) were being applied onto the brake drum continuously even when the lift motor and drum were running. As a result, the temperature of both left and right brake linings started to rise continuously to about 220^{o}C. Finally, at simulation time 03:25:00, the lift car was found moving while the landing door was still at open position, and an unintended car movement occurred.

Figure 5: Thermal Imager



Remarks:

1. *Brake plungers started to operate sluggishly.*
2. *Brake plungers started to nearly stop moving, making the brake linings (both left and right) being pressed onto the brake drum continuously even when the lift motor and drum were still in operation. As a result, the temperature of both left and right brake linings started to rise.*
3. *Brake plungers started to stop moving, making the brake linings (both left and right) being pressed onto the brake drum continuously even when the lift motor and drum were still in operation. The temperature of both left and right brake linings continued to rise.*
4. *Unintended car movement occurred.*

Figure 6: Results of On-site Simulation Test

e) When the braking system was dismantled for investigation, the brake coil housing and brake plungers were found not lubricated for a long time so that dark dried lubricant was found on their surfaces. Figures 7, 8 and 9 show the inner part of the brake coil housing, and the conditions of the left brake plunger and that of the right brake plunger respectively, revealing the lack of lubrication between the surfaces of the brake coil housing and the plungers, and the frictional forces so generated obstructed the normal smooth operation of the brake plungers occasionally.

Figure 7: Brake coil housing

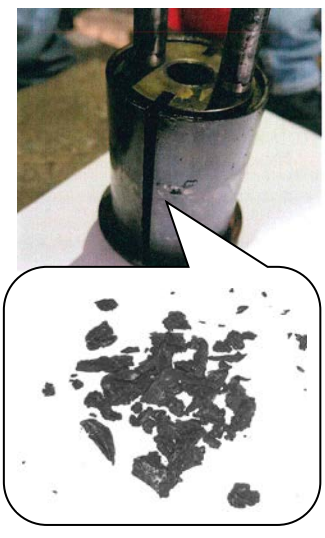


Figure 8: Condition of left brake plunger(Dark dried lubricant was found)

Figure 9: Condition of right brake plunger (No lubricant was found)

f) Another on-site simulation test revealed that either the left or right brake lining, if in good conditions, would be able to brake the lift.

5.2 Investigation Findings by a Mechanical Engineering Expert

a) On the left brake lining of the Incident Lift, there should be ten stainless steel screws for fixing the lining to the brake pad, with the head of one screw being seriously worn out (Screw A), and one screw was lost (Screw B) (Figure 10). However, on the right brake lining, all the ten stainless steel screws mounting the brake lining on the brake pad were intact (Figure 11). It was observed from the cross section of a non worn-out screw in the left brake pad (Figure 12) that the head of worn-out Screw A as shown in Figure 10 should have been worn out by around 3 mm.

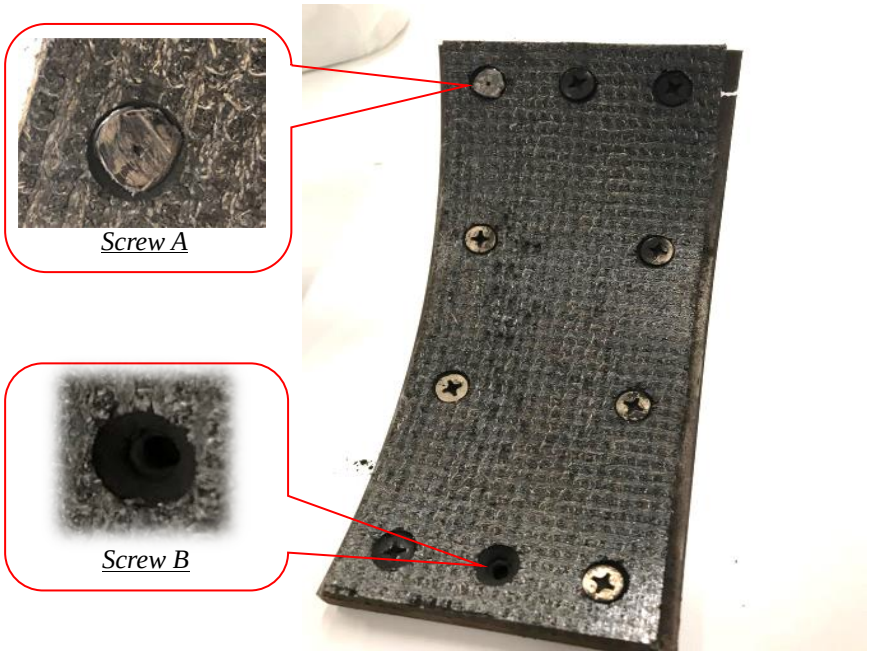


Figure 10: Left brake lining - Head of Screw A was seriously worn out while Screw B was lost

Figure 11: Right brake lining with all 10 mounting screws

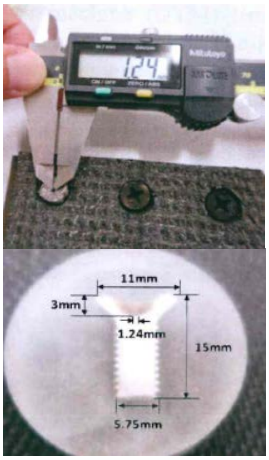


Figure 12: Cross section of a non-worn out screw

b) Two different scratch marks were observed at the brake drum (Figure 13). The scratch marks match well with the installation positions of Screw A and Screw B at the left brake lining as mentioned in paragraph 5.2(a) above. It was believed that screw head A had been scratched with the brake drum for certain time so that it had been severely worn out. The scratch marks on the drum matching with Screw B also showed that such scratching had happened between Screw B and the drum.

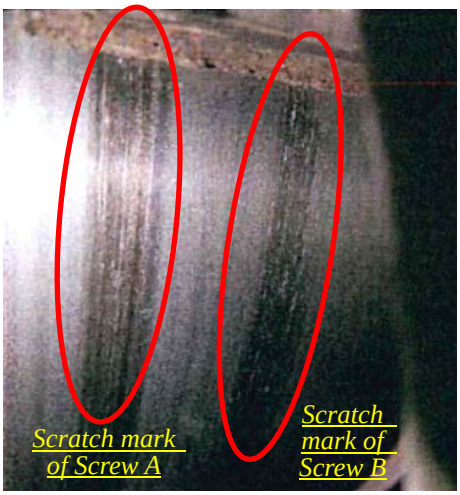


Figure 13: Scratch marks observed at the corresponding locations of Screw A and Screw B on the brake drum

c) A tribological test on the brake linings of the Incident Lift and new brake linings made of the same materials as those of the Incident Lift was performed. It was found that the coefficient of friction (COF) of the incident brake lining was lower than that of the new one. Figure 14 shows the results of the experiments.

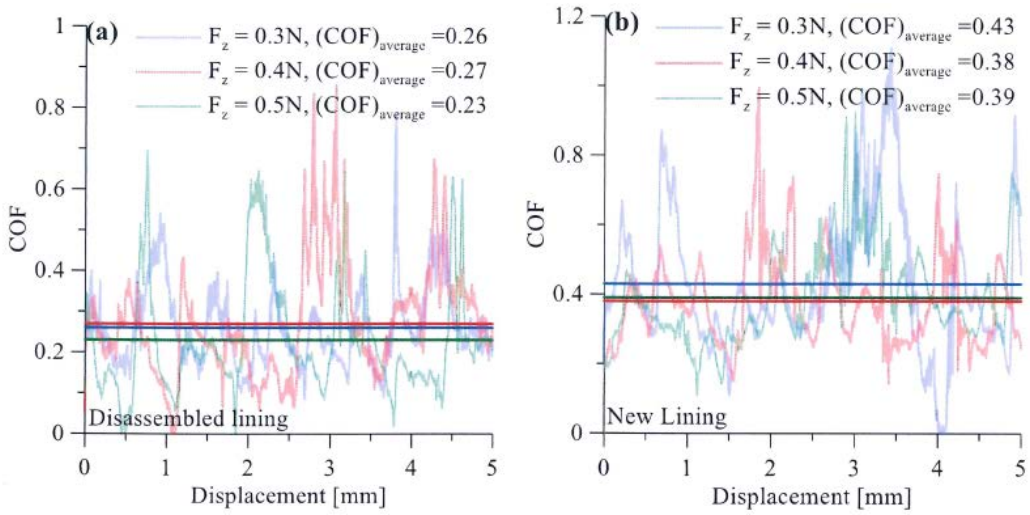


Figure 14: Results of the experiments for the incident brake lining (left) and the new brake lining (right)

d) A compression test on the new brake lining made of the same materials as the brake linings of the Incident Lift was performed. It was revealed that the vertical force applied to the brake lining surfaces to maintain a constant compression (0.5mm) dropped significantly under high brake lining temperature (around 220°C) compared with normal room temperature (Figure 15). It implies that the braking force of the brake linings would be reduced significantly under high temperature (around 220°C).

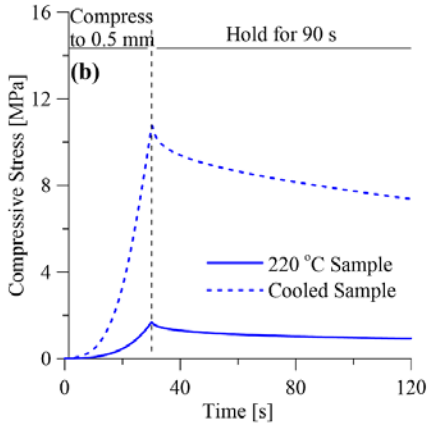


Figure 15: Compression test results for new brake lining under 220°C brake lining temperature and being cooled down to room temperature condition.

5.3 Investigation Findings by an Electrical Engineering Expert

a) A hysteresis loop test on the brake plungers was performed to check if there was any magnetic saturation problem which could lead to abnormal operation of the plungers. The test was conducted on both new brake coil and plunger, as well as the brake coil and plunger of the Incident Lift. Results of the experiments showed that no magnetic saturation was observed for the brake plunger of the Incident Lift.

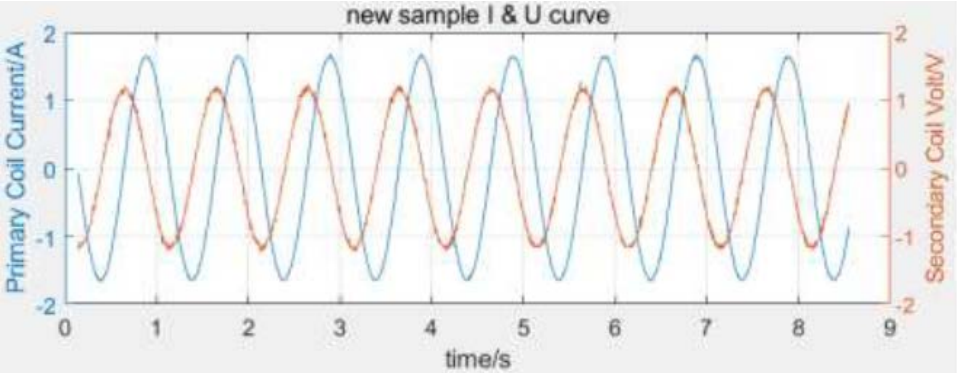


Figure 16: Relationship between primary coil current and secondary coil voltage with 90 degree phase difference for new brake coil and plunger

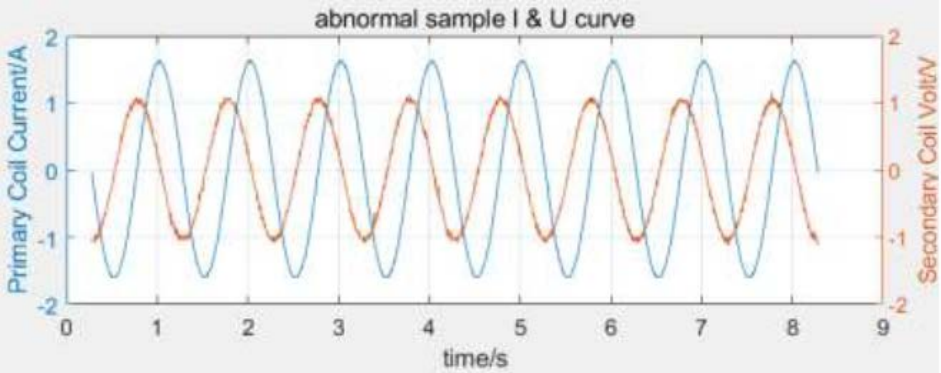


Figure 17: Relationship between primary coil current and secondary coil voltage with 90 degree phase difference for brake coil and plunger of the Incident Lift

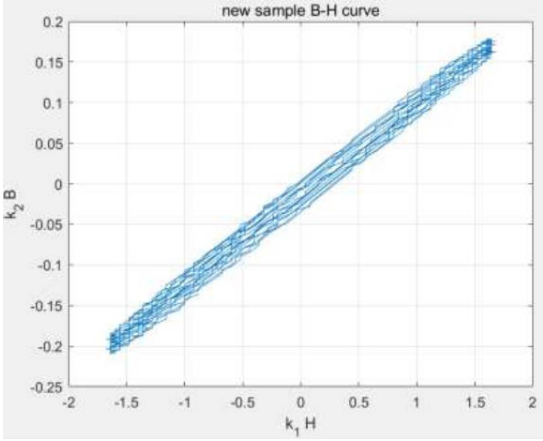


Figure 18: B-H curve for new brake coil and plunger

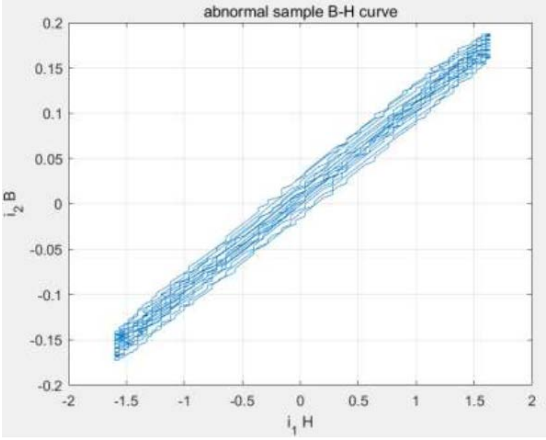


Figure 19: B-H curve for brake coil and plunger of the Incident Lift

b) The associated electrical components, including the brake solenoid, were inspected, tested and examined, and found to function properly. It can be concluded that the conditions of the brake coil of the Incident Lift and its power supply were normal. There was no evidence showing that the brake coil and its power supply were the cause of the incident.

6. Root Cause Analysis

6.1 Based on the above investigation findings, all safety switches and control circuitries as well as associated electrical components (including the brake solenoid) were tested and found to be in normal conditions.

6.2 Lift expert found that the brake plungers did not move smoothly and their movement was finally jammed during on-site simulation tests. Dark dried lubricant was found on the surfaces of the brake coil housing and the brake plungers, so that there was insufficient lubrication between the sliding surfaces of the brake plungers and the brake coil housing and the movement of the plungers would be occasionally jammed when the frictional force at the sliding surfaces was too high. This would lead to incomplete opening of the brake arms when the Incident Lift was in operation, making the brake linings remain in contact with and rubbing against the brake drum surface, thus resulting in overheating of the brake linings (Figure 20). When the brake linings were overheated, their braking force would be significantly reduced according to the above laboratory tests carried out by the mechanical engineering expert.

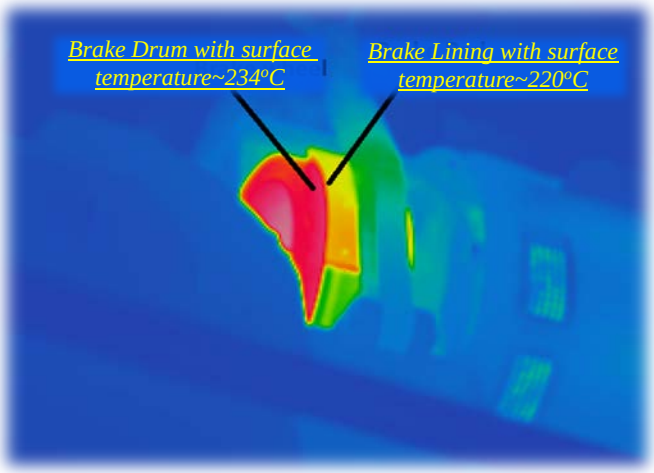


Figure 20: Overheating of Brake Pad

6.3 The rubbing of brake lining against the brake drum and the vibration so generated at the left brake pad loosened the fixing screws of the brake linings, thereby leading to the loss of one of the fixing screws (i.e. Screw B), while the other one (i.e. Screw A) was protruded out of the lining and scratched with the brake drum surface. The protruded screw reduced the contact surface area between the brake lining and brake drum, thereby further reducing the braking force of the brake to stop the lift (Figure 21). As a result, there was insufficient braking force to hold the lift system when the lift

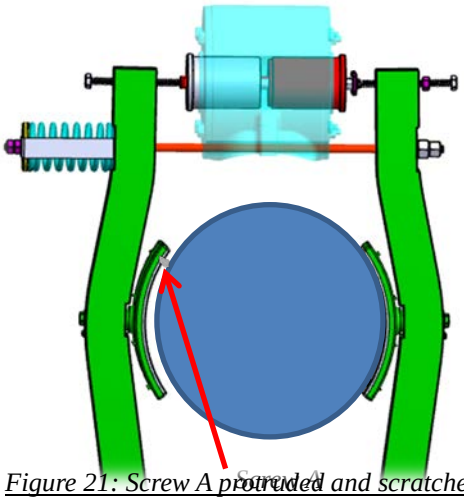


Figure 21: Screw A protruded and scratched with the brake drum surface. The reduced contact surface between the brake lining and brake drum further reduced the braking force.

stopped at 7/F to answer the lift call with lift door opened. As there was only one passenger (i.e. the victim), the counterweight was heavier than the lift car with one passenger and so the lift car moved unintentionally upward.

6.4 Four unintended car movements of the Incident Lift were observed from the CCTV footage prior to the incident, during which the loosened and protruded screw head had been ground and scratched with the rotating brake drum during these occasions as well. During the incident, the loosened and protruded screw head became flushed with the brake lining after continuous grinding with the brake drum, so that eventually the left brake pad was able to press on the brake drum to stop the lift.

7. Conclusions

Based on the technical investigation findings, the EMSD concludes that the lift incident at Paris Court, Sheung Shui Town Centre, New Territories on 11 May 2018 was caused by the ineffective brake system of the Incident Lift due to the following reasons:

a) occasional jamming of the movement of the brake plungers due to lack of lubrication for a long time inside the brake coil housing;

b) overheating of the brake linings due to their rubbing against the brake drum caused by jammed movement of the brake plungers and so the incomplete opening of the brake pads; and

c) rubbing of brake lining against the brake drum and the vibration so generated loosened the fixing screws of the left brake lining, and the loosened fixing screw (i.e. Screw A) protruded out of the lining and pressed on the brake drum surface, thereby reducing the effective braking surface and braking force. Together with the overheating of the right brake lining, there was insufficient braking force to stop the lift at 7/F.

8. Measures Taken after the Incident

8.1 After the incident, as a prudent measure, all registered lift contractors maintaining lifts of “Guangri” brand (totally 91 nos. of lifts, excluding the Incident Lift) were requested to carry out special inspection. The special inspections were completed in two weeks after the incident and no abnormality was found. The EMSD further requested the registered lift contractor maintaining the Incident Lift to conduct special inspections for all 389 lifts under its maintenance, which were completed and no abnormality was found.

8.2 The EMSD issued Circular No. 6/2018 dated 9 July 2018 to remind all registered lift contractors to properly carry out brake system overhauls according to the manufacturers' recommendations. Overhauls of the brake system of all "Guangri" lifts were carried out and inspected by the EMSD afterwards, and no abnormality was found.

8.3 The EMSD will continue with the criminal investigation into the case and prosecution/disciplinary actions against the registered lift contractor, registered lift engineer(s) and/or registered lift worker(s) concerned will be considered if non-compliance with the Lift and Escalator Ordinance, Cap. 618, is found in the investigation.

~End of Report~

Appendix I – Basic Structure of an Electric Traction Lift