Report from the Expert Panel

on the

Cabin Falling Incident

occurred on 11 June 2007

at the

Ngong Ping Ropeway

(Prof. Dr. Gabor Oplatka)
Chairman

(Prof. Dr. Josef Nejez)
Deputy Chairman

(Ir. Frank Chan, JP)
Member

Date : 30. juli 2007

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Introduction

In the evening of 11 June 2007, at about 8:00 pm, a cabin, of number 21, was found lying on the ground next to Tower 2B of the Ngong Ping ropeway. The cabin suffered serious damage, and was later verified as one that had fallen from the ropeway at about 50 m above ground level. The photo of the wreckage of cabin no. 21 was given in figure 1.

Figure 1 – Wreckage of cabin no. 21

2. There was no passenger inside the cabin, and the location where the cabin landed was a bushy landscape area next to Tower 2B. There was no injury to persons and no damage to properties resulting from the incident.

Figure 2 – Vicinity of Tower 2B

3. At the material time of the incident, the ropeway was undergoing an annual examination, not under extraordinary weather conditions, carried out by an independent surveyor appointed by Skyrail-ITM (HK) Ltd. (Skyrail). Skyrail also deployed maintenance personnel to participate in the annual examination. The annual examination was a statutory procedure required under regulation 20 of the Aerial Ropeways (Operation and Maintenance) Regulations, Cap. 211A.

4. An Expert Panel was appointed by the Government to conduct detailed investigation into the incident, aiming at ascertaining the cause, reviewing the design, operation, maintenance and management of the ropeway, identifying remedial measures to prevent recurrence of similar incident, and recommending prerequisite requirements for re-opening of the ropeway for use by the public. The Expert Panel comprises the following three members, with secretariat and technical support by the Electrical and Mechanical Services Department (EMSD).

Chairman	:	Prof. Dr. Gabor Oplatka
Deputy Chairman	:	Prof. Dr. Josef Nejez
Member	:	Ir Frank Chan, JP

5. This report presents the results of the investigation by the Expert Panel on the cabin falling incident at the Ngong Ping ropeway, occurred on 11 June 2007. The Report is divided into three parts as follows:

Part 1 - Cause of the incident, and recommendations to prevent recurrence of similar incident in future

Part 2 - Assessment of the design, operation, maintenance and management of the ropeway

Part 3 - Prerequisite requirements for re-opening of the ropeway for use by the public

Background

6. The Ngong Ping ropeway was open to public in September 2006. It is of bi-cable design, of length 5.7 km, having a maximum passenger carrying capacity of 3,500 persons per hour per direction. At full capacity, it carries a total of 109 cabins, each can accommodate up to 17 passengers. The maximum operating speed of the ropeway is 7 m/s. Since opening to the public in September 2006, the operating speed was limited to 5 m/s [1], for the purpose of allowing the ropeway to overcome initial teething problems, all of which were not safety-related, but of concern on reliability which is required to be enhanced to meet public expectation.

7. The ropeway has a circulating route that enables passengers to travel in both directions at the same time. It has two terminals at Tung Chung and Ngong Ping, two angle stations at Airport Island and Nei Lak Shan, and eight (8) intermediate towers, numbered as 1, 2A, 2B, 3, 4, 5, 6 and 7, with the number 1 tower closest to Tung Chung terminal. The ropeway is divided into two sections, each has its own driving units, braking system, and separate rope systems for the cabins :

Section I – this is the shorter section from Tung Chung Terminal to Airport Island Angle Station, of length about 0.6 km;

Section II – this is the longer section from Airport Island Angle Station to Ngong Ping Terminal, of length about 5.1 km.

8. The angle station at Airport Island houses the drive units, the braking system and provides the first turning point for the ropeway. The other angle

[1] EMSD letter to MTRCL ref. (47) in EM GL/03/10 SF11(A1) dated 15 Aug 2006.

station at Nei Lak Shan provides the second turning point for the ropeway before the Ngong Ping Terminal.

9. The Ngong Ping ropeway, being of bi-cable design, employs two types of ropes, namely the track rope and the hauling rope, to perform two distinct functions, as per illustrated in figure 3 :

> The track rope, which is a stationary rope of nominal diameter 70 mm, serves to carry the weight of the cabins and provides a smooth track for the cabins to move in the direction of travel.
>
> The hauling rope, which is a moving rope of nominal diameter 42 mm below the track rope, functions to pull the cabin to travel along the track rope through a detachable grip. This grip will automatically open when the cabin arrives at the terminal, such that the cabin will be released from the hauling rope and moves with a much lower speed along a conveying system for embarkation/disembarkation of passengers within the terminals.

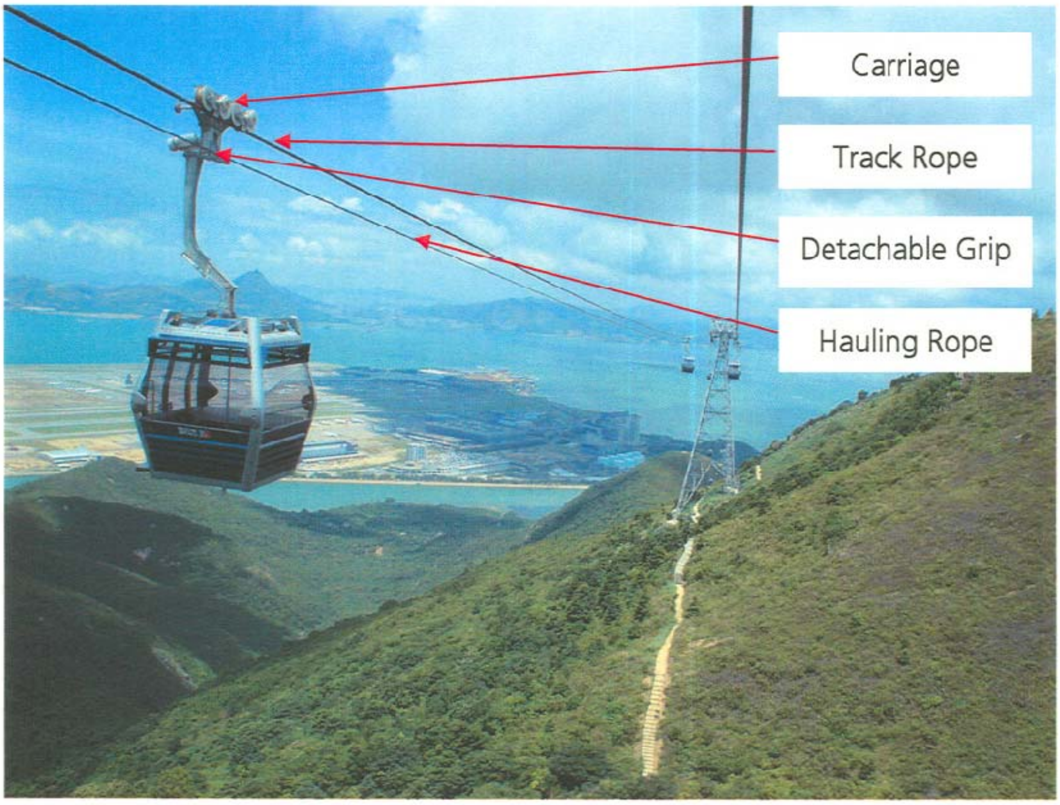


Figure 3 – Bi-cable ropeway and cabin

10. The plan view and the schematic diagram of the Ngong Ping ropeway were given in figures 4 and 5.

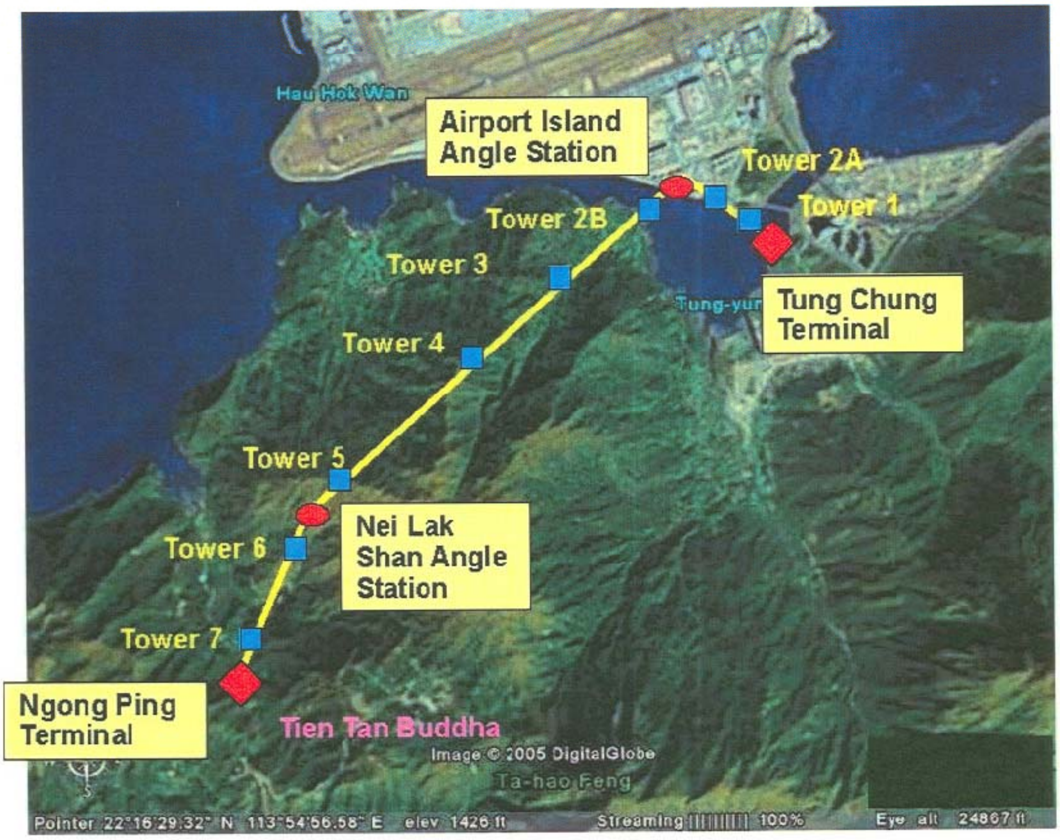


Figure 4 - Plan view of Ngong Ping ropeway

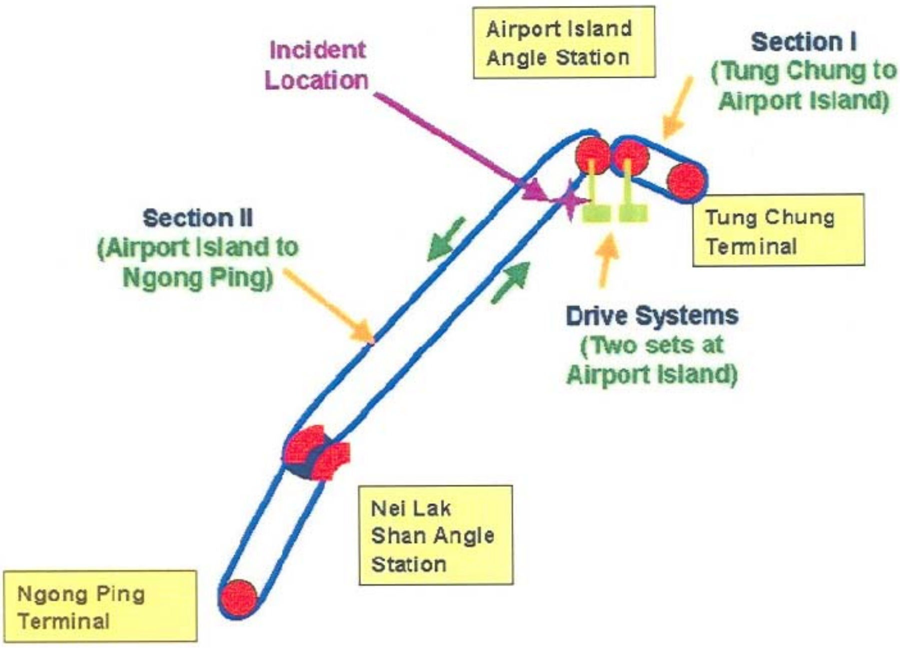


Figure 5 - Schematic diagram of Ngong Ping ropeway

PART 1

CAUSES OF THE INCIDENT, AND RECOMMENDATIONS

TO PREVENT

RECURRENCE OF SIMILAR INCIDENT

IN FUTURE

PART 1 - CAUSES OF THE INCIDENT, AND RECOMMENDATIONS TO PREVENT RECURRENCE OF SIMILAR INCIDENT IN FUTURE

Approach of the Investigation

11. The approach adopted by the Expert Panel in conducting the investigation is outlined as follows :

11.1 Analyse the data, in particular the braking curves and the time log of all related information retrieved from the Supervisory Control and Data Acquisition System (SCADA) of the ropeway.

11.2 Study and review the manufacturer's operation and maintenance (O&M) manual of the ropeway, to identify recommendations for the brake tests and associated measures that are considered relevant to the incident.

11.3 Interview concerned staff members of Skyrail, the independent surveyor, and representatives of the ropeway manufacturer and owner, as regards details and sequence of events before and after the incident.

11.4 Inspect, check and analyse ropeway components that were involved in the incident, including the damaged cabin no. 21 and its carriage, the track rope and the hauling rope, the damaged roller wheels on Tower 2B.

11.5 Conduct site measurements and desk-top analysis of the dynamic behaviour of cabins and the hauling rope.

11.6 Arrange for forensic examinations by the Government Laboratory and Hong Kong Productivity Council.

Observations and Findings

12. Visual inspection on the ropeway components after the incident revealed that :

12.1 In addition to the serious damage of the cabin no. 21, a total of thirteen rollers at the top of Tower 2B were damaged (figure 6), whereas scratch marks were observed on a few framework members of Tower 2B.

12.2 The track rope was found in a good working condition, except that there are shallow scratch marks for about 173 m in length (figure 7).

12.3 The hauling rope was found having minor surface damage at several spots along the length of the rope at or around the vicinity of the griping position of the derailed cabin (figure 8).

Figure 6 – Thirteen rollers at the Tower 2B were damaged

Figure 7 – A section of the 173 m long scratch mark found on track rope

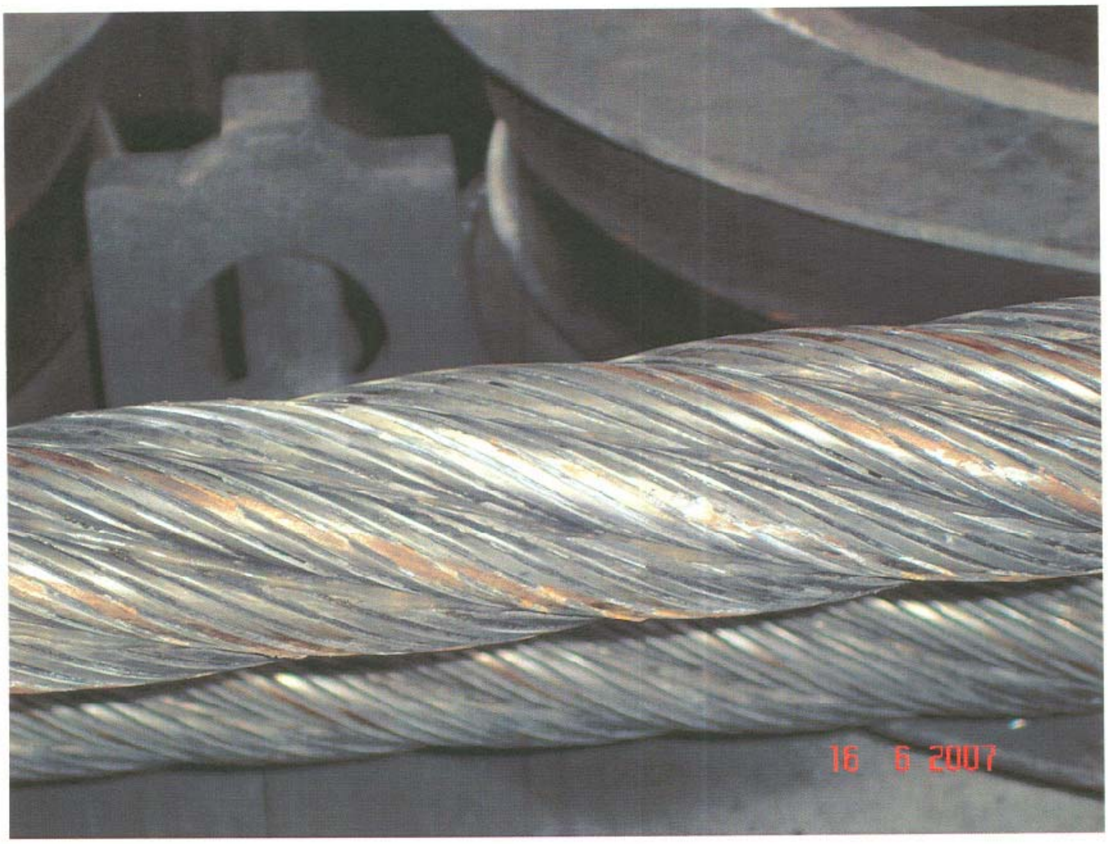


Figure 8 – Minor surface damage found on hauling rope

13. The Expert Panel conducted a series of examinations and tests on the ropeway system and its components, with particular attention given to the operation of the brake test during the annual examination carried out on 11 June 2007.

14. The service brakes of the ropeway drives are divided into two groups [2]. During normal operation, these brakes are actuated automatically with modulation, for the purpose of bringing the ropeway to a safe stop under controlled deceleration. The braking system provides manual testing control to simulate failure of the modulation, but to avoid excessive deceleration as a result of the simulation test, the ropeway manufacturer stipulated that the deceleration rate for Section I should be limited to within 2 m/s^2 and Section II to 1 m/s^2 [3].

15. The brake tests with empty cabins in the evening of 11 June 2007 were part of the annual examination, with the independent surveyor setting out the test schedule and the maintenance personnel of Skyrail performing manual operation of the ropeway system. One of the test items was to simulate the failure of modulation of one group of service brake. It was noted that, during the test, both groups of the service brakes were operated by the maintenance personnel at 19:39 which resulted in an excessive deceleration of 1.6 m/s^2 being applied to Section II of the ropeway.

16. Due to the excessive deceleration, the cabins were made oscillating in a forward-and-backward manner, and the hauling rope was also caused to swing with a wave motion in the vertical plane. Deriving from the inspection on the scratch marks made on the track rope, it was believed that at about 173 m from Tower 2B, the cabin no. 21 was thrown upwards and caused to derail from the track rope by the resultant of its own oscillating momentum and the excessive swinging of the ropes (figure 9).

[2] O&M Manual, section 3.3.2, Service Brake, Part C)1.2.

[3] O&M Manual, section 5.1, Braking Tests, Testing & Commissioning Report ref. A1, Part C) Manual.

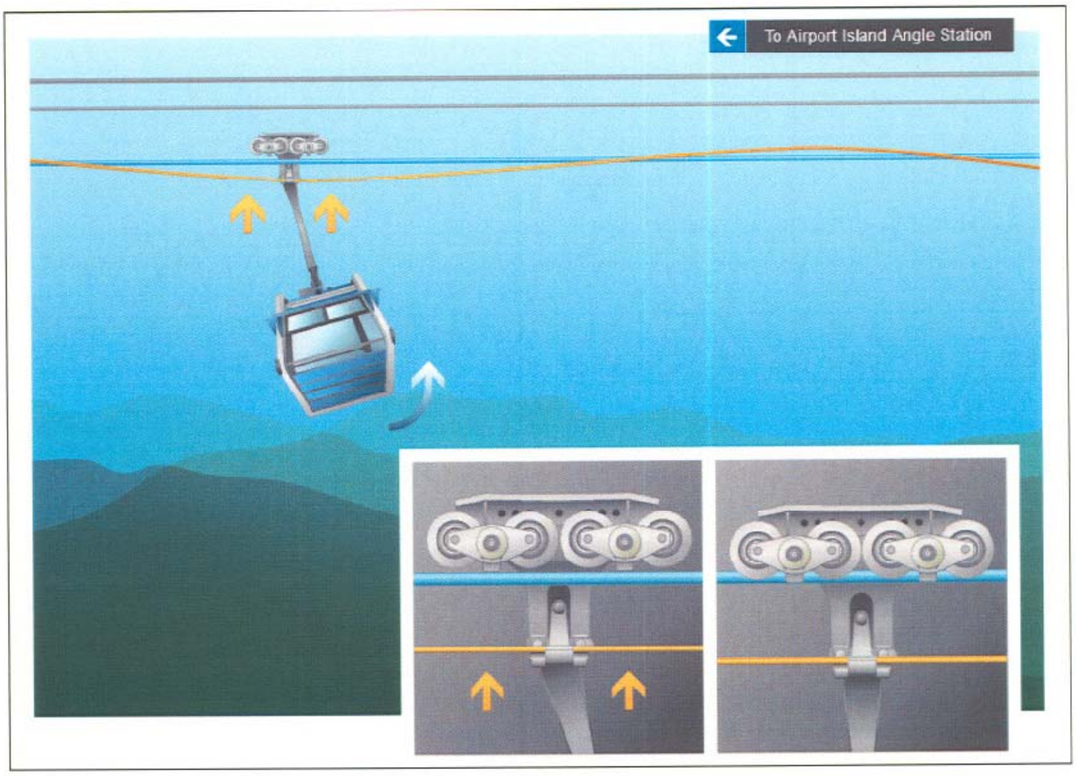


Figure 9 – Cabin no. 21 uplifted as a result of the oscillating momentum of the cabin and excessive swinging of the hauling rope (small figure on the right side shows the normal position of the carriage)

17. After the derailment at 19:39, it was evident that the cabin still hung on the track rope by the connecting shafts of the station guide rollers in a manner as per illustrated in figure 10. The derailment was not detected, and when the ropeway was re-started, the derailed carriage of the cabin no. 21 was pulled by the hauling rope moving in the direction towards Tower 2B. As it moved forward through gliding on the track rope, scratch mark on the track rope, abrasion on the lock nuts and transfer of lubricant from the track rope to the roller wheels were caused, as revealed by the following investigation findings :

17.1 a continuous stretch of 173 m of shallow scratch mark was found on the track rope from the point of derailment to Tower 2B;

17.2 abraded marks were observed at the underside of the lock nuts of the station guide rollers (figure 11), and

17.3 inner side of the station guide rollers were coated with a layer of grease which was found similar to the lubricant used for the track rope (figure 12). Confirmation by forensic examination conducted by the Government Laboratory was given at Appendix 1.

Figure 10 – Cabin no. 21 derailed and suspended on the track rope by the connecting shafts of the station guide rollers of the carriage

Figure 11 – Abraded mark found at underside of the lock nut of the station guide roller

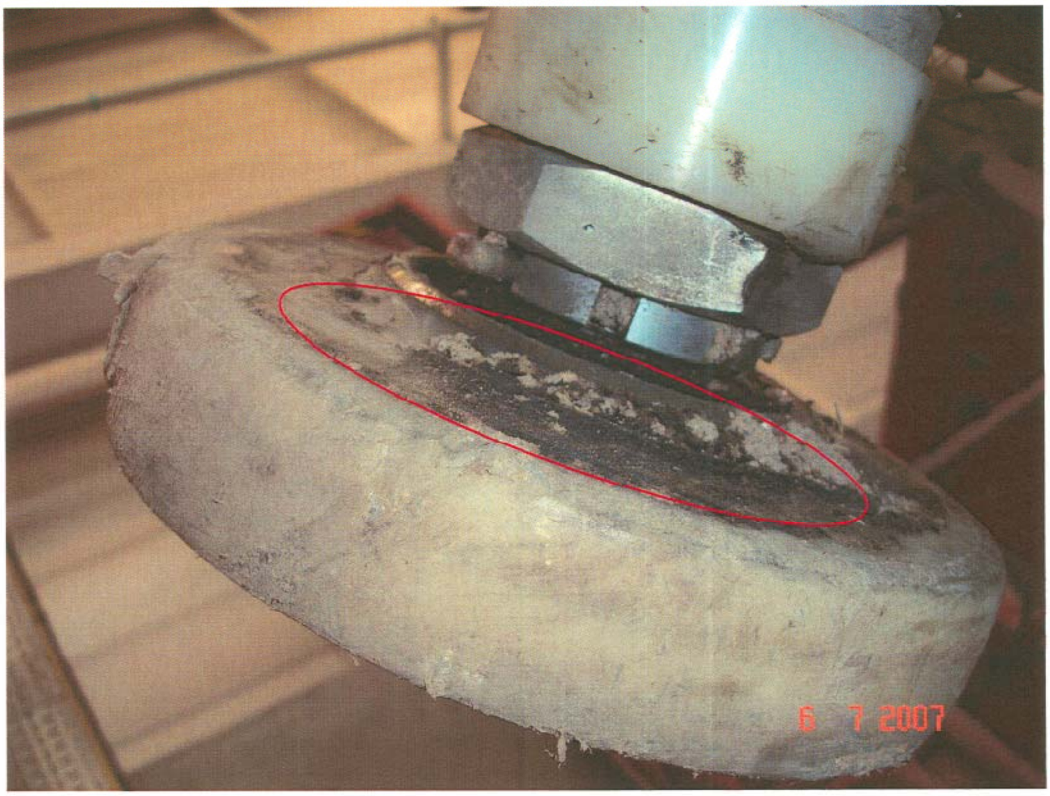


Figure 12 – Layer of grease found on the inner side of the station guide roller

18. As the derailed carriage of cabin no. 21 was in a misaligned position (figure 13), when the carriage reached Tower 2B, the detachable grip collided with the series of roller wheels mounted on top of the tower (figure 14 & 15). The collision caused damage to the roller wheels and also to the hauling rope grip. Figure 16 shows the damaged roller wheels after the collision. At about the position of the 11th roller wheel, the force resulting from the collision caused the derailed cabin to detach completely from the hauling rope. The cabin thus fell through about 50 m and collapsed on the ground next to Tower 2B.

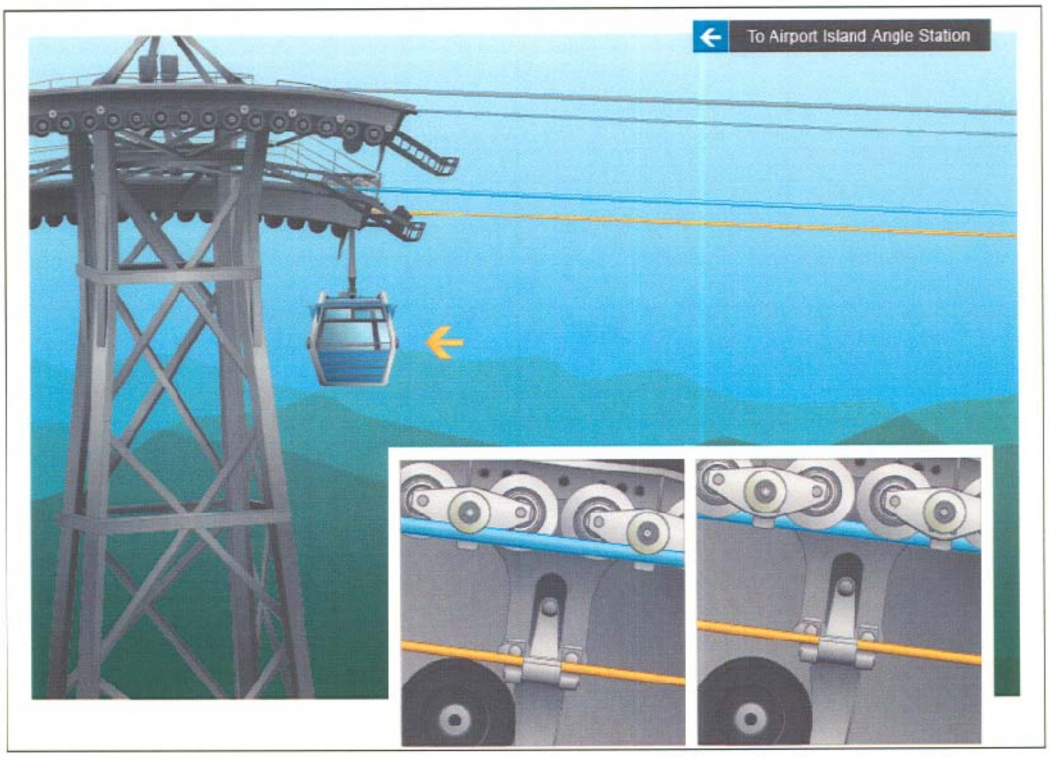


Figure 13 – Derailed cabin no. 21 reached Tower 2B in misaligned position (small figure on the left shows the misaligned position of carriage in details, whereas the one on the right shows the normal position)

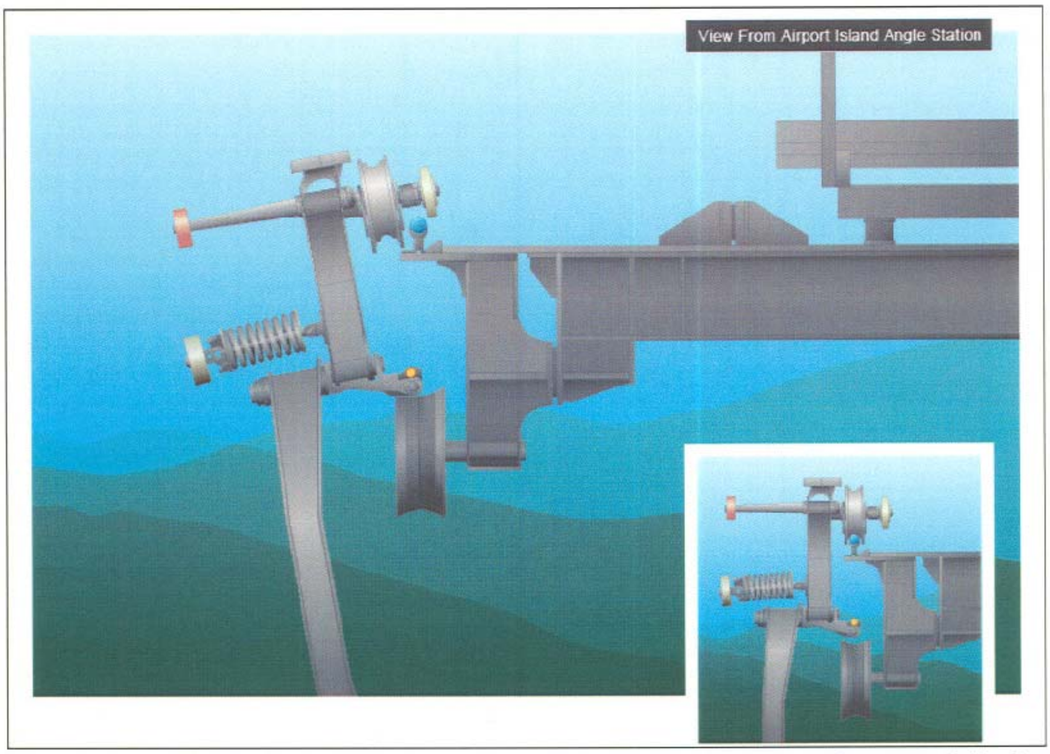


Figure 14 – Illustration of the moment when the cabin was about to fall after the detachable grip had collided with a series of roller wheels (small figure shows the normal position of carriage)

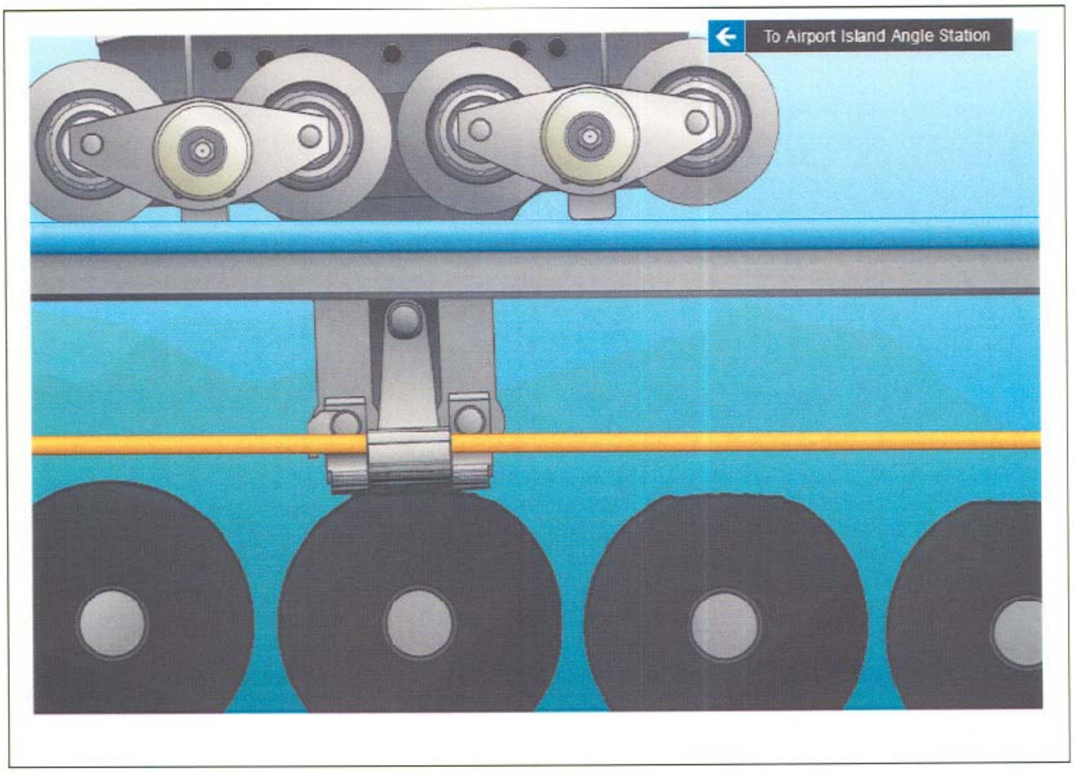


Figure 15 – The detachable grip collided with roller wheels on Tower 2B, causing damage

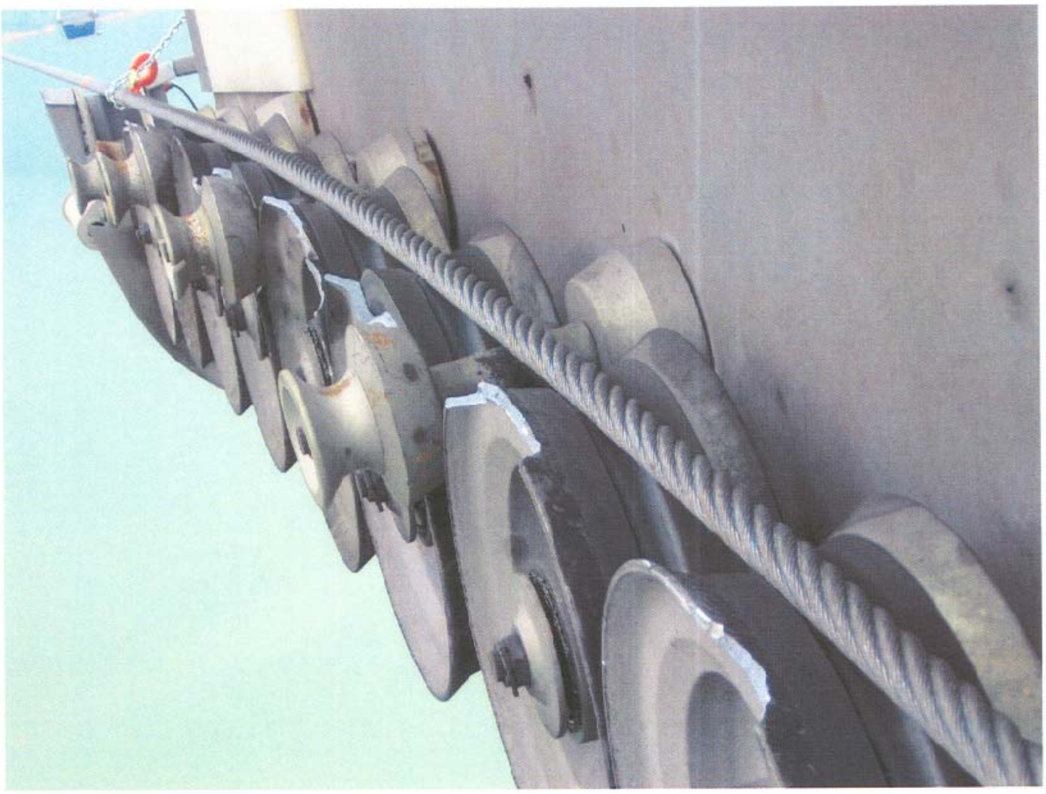


Figure 16 – Damaged roller wheels at Tower 2B after the collision with the hauling rope repositioned from the catchers

19. A detailed description of the brake test on 11 June 2007, and an analysis of the dynamic behaviour of the hauling rope and the cabins resulting from the brake test are given in Appendix 2.

Conclusion

20. The Expert Panel is of the opinion that improper operation of the service brakes of the ropeway during the annual examination on 11 June 2007 caused a high deceleration of the ropeway which exceeded the value stipulated by the ropeway manufacturer. This deceleration both rendered the track rope and the hauling rope to swing vertically and caused the cabin no. 21 derail from the track rope.

21. The falling of the cabin was a consequential event to the derailment, caused by the collision between misaligned carriage of the cabin and the roller wheels on top of Tower 2B.

22. It has to be pointed out that during normal operation of the ropeway, the possibility of simultaneous failure of both groups of service brakes is extremely remote. According to the design, the failure of the modulation control of any one group of the service brakes will automatically trigger an alarm signal and stop the ropeway by initiating a controlled deceleration. Leitner, the ropeway manufacturer, informed that there has not been any occurrence of simultaneous failure of both groups of service brakes in over 130 similar ropeway systems, either mono-cable or bi-cable systems having the same service brake configuration, installed between 2003 and 2006 by them. Thus brake test to simulate the failure of modulation of both groups of service brakes during annual examination is not necessary, and should not be allowed in any circumstances.

23. The Expert Panel considers that even after the partial derailment of the carriage that occurred after the service brake test at 19:39, the detachment and falling of the cabin no. 21 could possibly be avoided, if any or all of the following measures were taken :

23.1 Deployment of staff at various strategic locations along the ropeway to observe the oscillation of the cabins and the ropes.

23.2 Due care and diligence in examining the deceleration data and graph from the SCADA prior to proceeding further.

23.3 The brake test was suspended with the approach of the oncoming darkness.

23.4 Subsequent to observation of excessive deceleration during the brake test, advice from the ropeway manufacturer's local technical representative was sought in accordance with the O&M manual, on measures to be taken under such scenario.

23.5 Surveillance cameras of close circuit televisions (CCTVs) were installed at the top of Towers 2B, 3, 4, 5, 6 and 7 for monitoring of the deropement incident. Should the CCTV at Tower 2B remain functional in the evening of 11 June 2007, the condition of the incoming cabin no. 21 at Tower 2B could be observed.

Recommendations

24. The Expert Panel proposed the following remedial measures to prevent recurrence of similar incident :

24.1 Refresher training course for ropeway operators and maintenance staff to ensure adequate technical know-how in conducting annual examination of the ropeway.

24.2 Properly documented procedures and necessary works instructions to be prepared for all relevant items in the annual examination.

24.3 Introduction of a quality management system to ensure a safe and reliable ropeway operation, including annual examination.

24.4 Visual checks for possible cabin derailment must be carried out before system restarting wherever the ropeway experiences excessive deceleration.

24.5 Visual monitoring of the entire ropeway line for abnormal rope and cabin swing must be carried out during brake tests.

24.6 Operations which must not be carried out at the same time should be interlocked. For example, interlock to ensure that the two groups of the service brakes cannot be operated to simulate modulation failure at the same time during manual testing. It is worth pointing out that while interlocking of the service brake testing buttons is not an international practice in the ropeway industry, the Expert Panel considers that a fool-proof interlock device warrants consideration, the concept of which has been accepted by the ropeway manufacturer.

24.7 EMSD is recommended to attend the ITTAB (Internationale Tagung der Technischen Aufsichts-Behörden = International Meeting of Supervisory Authorities of Ropeways) to share experience with the international ropeway community.

PART 2

ASSESSMENT OF

THE DESIGN, OPERATION, MAINTENANCE

AND

MANAGEMANT OF THE ROPEWAY

PART 2 - ASSESSMENT OF THE DESIGN, OPERATION, MAINTENANCE AND MANAGEMANT OF THE ROPEWAY

Approach of the Assessment

25. The approach adopted by the Expert Panel in conducting the assessment is outlined as follows :

25.1 Conduct on-site inspection and audit of the ropeway by overseas expert.

25.2 Review the previous service disruption incidents and the performance of the ropeway operating company in this regard since the ropeway was opened for public use on 18 September 2006.

25.3 Review the observations and findings arising from the random inspections conducted by EMSD.

25.4 Review operation records of the ropeway, including fault log, duty roster, training and overtime record of staff.

25.5 Inspect and examine maintenance schedule, procedures, work instructions, service log and related records.

25.6 Review record of interview and information given by concerned staff members of Skyrail, representatives of the ropeway manufacturer and owner, as regards operation and maintenance of the ropeway.

25.7 Examine the ropeway performance review reports previously conducted by EMSD in January 2007 and TÜV SÜD in May 2007.

25.8 Review spare part inventory and management system of the ropeway operating company.

On-site inspect and audit of the ropeway by overseas expert

26. During the investigation of the incident, the overseas expert also

conducted on-site inspection and audit of the Ngong Ping ropeway. Some observations and findings are given in Appendix 3.

Review of previous service disruption incidents

27. Since the opening of the Ngong Ping ropeway for public use in September 2006, there were altogether twenty-two major incidents leading to frequent service interruptions. Those incidents resulted in out-cry from dissatisfied passengers, and drew public attention on the reliability of the ropeway system.

28. Discounting those interruptions due to adverse weather conditions and initial system incorrect settings, there were :

- three major incidents which were found to be caused by component design imperfection, and

- eleven major incidents which were found to be caused by operation blunders, poor works coordination, poor workmanship, inadequate operation awareness, poor maintenance and stock management.

29. Paragraphs 30 to 38 below give an assessment of the Expert Panel on the design, operation, maintenance and management of the ropeway.

Review of the incidents relating to design of the Ngong Ping ropeway

30. Table 1 below gives an account of three service interruption incidents which were caused by component design imperfection.

Table 1

Ref No.	Date & Duration of Service Disruption	Brief Description
D1	8.10.06 58 minutes	Inadequate clearance between the hauling rope and the shaft of the rope catcher at the tower, ground fault alarm was activated due to touching of the two.
D2	15.10.06 55 minutes	Premature failure of an electrical part in the control system, causing intermittent service interruption.

D3	6.2.07 15 minutes	Mis-count of the number of cabin inside cabin storage area during cycling-on operation, causing delay in service.

31. Having studied the operation of the ropeway, its physical layout and construction, control arrangement, safety provisions, design philosophy in respect of selecting the bi-cable option, the Expert Panel is of the opinion that the design of the Ngong Ping ropeway is in line with the prevailing international standards and practices for meeting the various parameters in the design intent, including passenger flow, topographical constraints, wind speed resistance and environmental consideration.

32. On the other hand, the Expert Panel noted that certain components of the ropeway system, including v-belt pulleys in stations, track ropes, and connection pins between hangers and the cabins showed signs of rusting which would not be expected for a system that was put into service for one year (figures 17, 18 and 19). Signs of rusting also existed on the spare parts inside the cabin storage area. Those components should be treated for corrosion protection, or replaced with better quality ones that are suitable for the humid environment of Hong Kong, especially in the north Lantau area.

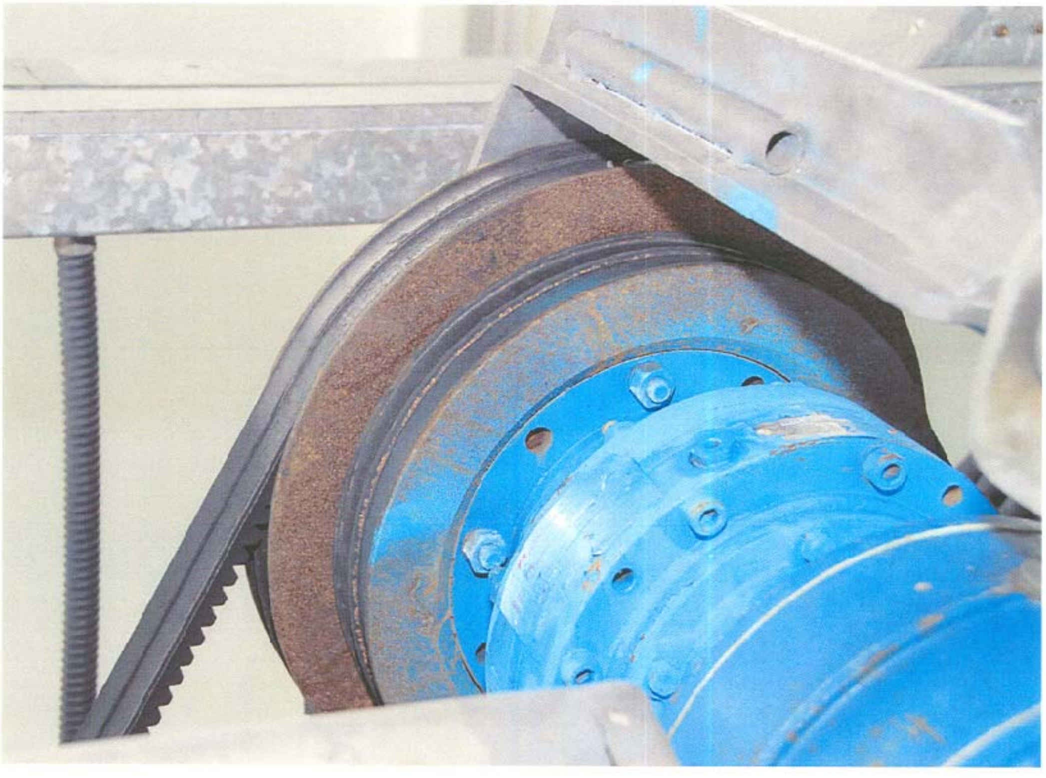


Figure 17 – Close up view on the rusty v-belt pulley

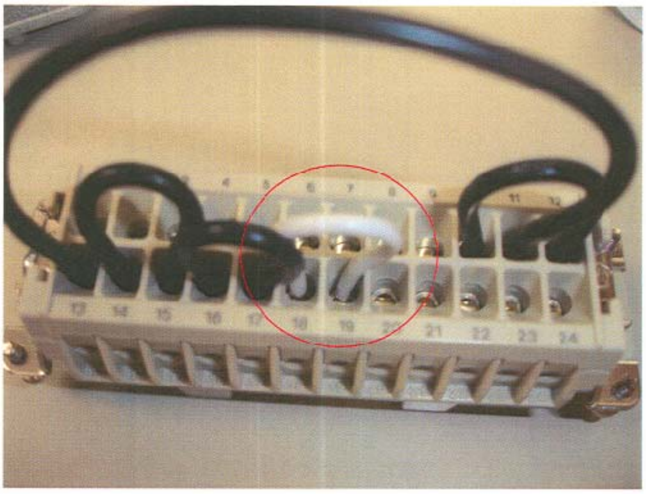
Figure 18 – Close up view on the track rope with rust

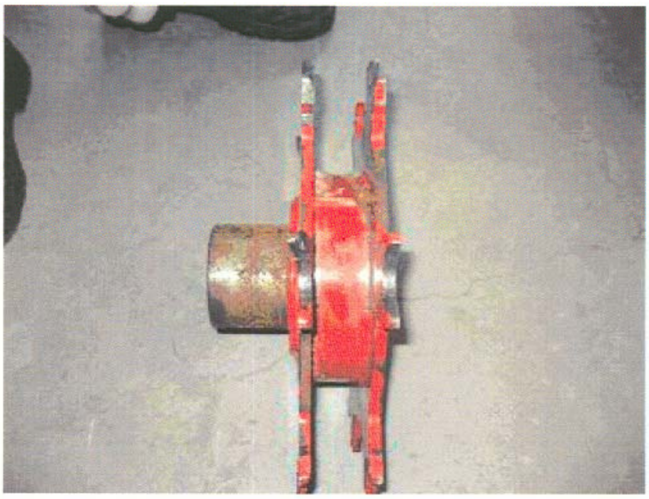
Figure 19 – Spare parts stored inside cabin storage area with sign of rust

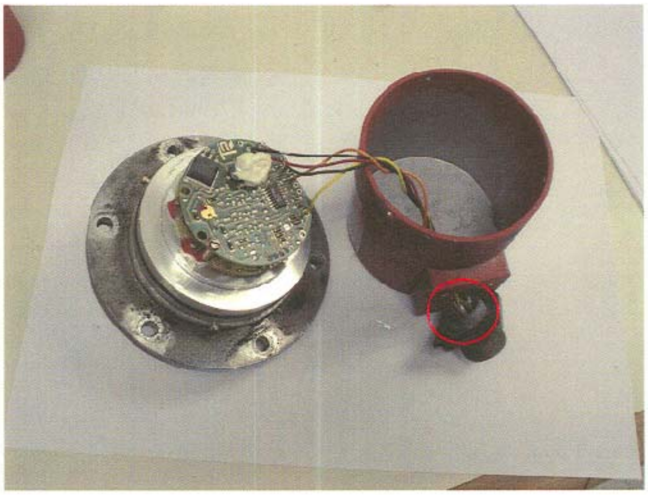
Review of the incidents relating to operation, maintenance and management of the Ngong Ping ropeway

33. Table 2 below gives an account of the eleven service disruption incidents which were caused by operation blunders, poor works coordination, poor workmanship, inadequate operation awareness, poor maintenance and stock management, and led to prolonged service disruptions.

<u>Table 2</u>

Ref. No.	Date & Duration of Service Disruption	Brief Description
OM1	30.9.06 51 minutes	An incorrect control function plug was used at Tung Chung Terminal, leading to improper functioning of the control system which subsequently tripped the system operation.  Figure 20 - A jumper (in red circle) was found missing from the plug
OM2	15.10.06 59 minutes	The maintenance work conducted at night caused improper cabin spacing resulting in the ropeway system not ready for operation on time in the morning of 15.10.06.

OM3	27.10.06 4 hours 20 minutes	A drive sprocket in the cabin storage area was jammed and one of the teeth was damaged. There was no spare sprocket in stock, and therefore requiring repair of the damaged sprocket, leading to service interruption for over 4 hours.  Figure 21 - Drive sprocket with one of the teeth damaged
OM4	28.11.06 23 minutes	One of the friction belts was found loosen, causing improper cabins separation and resulting in tripping of the system. Frequency of checking and adjustment of belt tension was considered inadequate.
OM5	1.1.07 1 hour 12 minutes	A friction tyre deflated during operation, resulting in tripping of the system. Frequency of checking and maintaining the tyre pressure was considered inadequate.

OM6	3.1.07 1 hour 18 minutes	Water ingressed into an electronic encoder at Airport Island Angle Station, causing tripping of the system. Encoder electronics parts are not well insulated from moisture and dirt.  Figure 22 - Malfunctioned encoder with position where water and oil like dirt found was circled in red
OM7	17.1.07 6 hours 20 minutes	Dirty station rollers trapped moisture, resulting in "grounding fault" warning signal and tripping of the system. Checking and cleansing of station rollers was considered inadequate.
OM8	7.2.07 26 minutes	One of the friction belts was found loosen, causing slippage in the belt drive and resulting in tripping of the system. Frequency of checking and adjustment of belt tension was considered inadequate.
OM9	9.4.07 51 minutes	One of the friction belts was found loosen, causing slippage in the belt drive and resulting in tripping of the system. While adjusting the belt tension, the maintenance technicians over-tightened an adjustment bolt thus causing damage to the bolt threads. Subsequent replacement of the tensioning bolt caused extended service interruption.

OM10	11.5.07 2 hours	A spring-loaded damping roller was damaged during operation, resulting in tripping of the system. The shaft of the damping roller showed heavy surface abrasion, a sign of inadequate routine checks and maintenance.  Figure 23 - Close up view on the shaft with heavy surface abrasion
OM11	11.6.07 from 19:52, 11.6.07 onwards	Cabin no. 21 fell and collapsed next to Tower 2B. The incident was caused by improper operation of service brakes during annual examination.  Figure 24 - Wreckage of cabin no. 21 after the incident

34. EMSD has been closely monitoring the safety performance of Ngong Ping ropeway since its public opening. During the past nine months, EMSD has provided guidance and advice to Skyrail with a view to enhancing reliability of the ropeway. The causes for advice can be grouped into two categories, namely, arising from observations during the investigation of the various service disruption incidents and during random inspections conducted by EMSD. It is evident from tables 3 and 4 below that EMSD has also covered detail operation and maintenance of ropeway on top of its regulatory role.

Table 3 – Advice on Improvement arising from EMSD's Investigation of Service Disruption Incidents

*(* denotes those improvement items that have been completed by Skyrail, with close monitoring by EMSD)*

Ref. No.	Incident Date	Advices given to / Actions taken by Skyrail
OM1	30.9.06	● Ensure all function plugs for remote control console are with proper connections. * ● Document and implement engineering changes properly. *
D1	8.10.06	● Provide nylon sleeves to the shafts of rope catchers at Tower 3, as an interim measure. * ● Follow-up with Leitner for new design of rope catcher to allow additional clearance between the rope catcher shaft and the hauling rope. * ● Re-arrange positions of CCTV on Tower 3, 4 & 7 with a view to improving the monitoring of the ropeway conditions at and around the towers. *
OM2	15.10.06	● Implement proper method for lubricating the track rope such that resumption of operation of the ropeway system could be effected on time the next morning. *
OM3	27.10.06	● Stock spare sprocket of chain #4. * ● Source sprocket locally, as an alternative supply. * ● Seek confirmation from Leitner that the cabin conveying system is of suitable duty grading and the parts are of appropriate specification for the design application. * ● Provide motor torque limiting device for the cabin conveyors. * ● Provide a manual override to the computerized operation of the cabin conveyors. * ● Add a display of running current of the conveyors into the SCADA (Supervisory Control and Data Acquisition) system. * ● Request Leitner to investigate the cause of rope cross-over during cycling, and appropriate improvement measures. * ● Conduct laboratory test on the chemical and mechanical properties of the deformed sprocket, and action if necessary. * ● Review the conveyor system of the cabin storage area for enhancing service availability. *

OM5	1.1.07	● Establish a marking system to identify leaky friction tyres. * ● Design and provide inspection facility for tyre leakage. * ● Incorporate tyre pressure gauge for all friction tyres. * ● Adopt measures to prevent rusting on the bolts of tyre hubs. * ● Review constantly pressure setting for friction tyre. * ● Examine if there is correlation between the warning signal "Collision of Vehicle" following by signal "Minimum Grip Force", in the event of tyre losing pressure. *
OM6	3.1.07	● Increase maintenance frequency for encoders & other electronic devices which are used in outdoor environment. * ● Review suitability of enclosure protection for equipment used outdoor. * ● Develop measure for preventing condensation inside encoder. *
OM9	9.4.07	● Improve record system for logging daily maintenance activities. * ● Enhance the frequency of checking of mounting bolts of spacer and use appropriate measure (e.g. thread glue, etc.) to prevent loosening of the mounting bolts. * ● Arrange refreshment course to equip the maintenance team with correct recovery procedure. * ● Provide lock nuts and lining to the adjustable bolts for the spacer. *
OM10	11.5.07	● Check alignment and working condition of all spring-loaded damping rollers. * ● Ensure availability of enough stock for spring-loaded damping rollers. ● Regular apply lubrication and conduct inspection on the moving parts of the spring-loaded damping roller and other similar mechanisms.

Table 4 – Advice on Improvement arising from Random Inspections by EMSD

*(* denotes those improvement items that have been completed by Skyrail, with close monitoring by EMSD)*

Ref. No.	Date	Observation / Advice given to Skyrail
1	31.7.06	Observation : Newly employed maintenance technician was found working alone to attend fault during ropeway operation.

		Advice given :	Strengthening the on-site supervision of the maintenance activities to ensure effective fault rectification. *
2	2.8.06	Observation : Advice given :	Outer wires of the track rope were found to be dislocated. Close monitoring the condition of the track rope with dislocated wires to ensure rope integrity. *
3	17.9.06	Observation : Advice given :	Rusting was found on the actuator for cabin door lock. Replacement of the original actuator for cabin door lock by unit made of stainless steel. *
4	10.10.06	Observation : Advice given :	A fault involving the encoder of main motor occurred during operation and there was no spare encoder for replacement. Ensure adequate stock and timely replenishment of spare encoder for main motor. *
5	15.10.06	Observation : Advice given :	Repeated cabin spacing faults since public opening. Recording and analyzing the spacing distance of the cabins for improving the software for anti-collision alarm. *
6	15.10.06	Observation : Advice given :	Serious corrosion was found at the connection port of the proximity switch. Use of longer cable for proximity switches so as to eliminate the use of plug and socket which are prone to corrosion. *
7	16.10.06	Observation : Advice given :	The last cabin with passengers was not correctly reported by an operator, risking to have passengers trapped on line after operation. Reminding all controllers & operators to follow the proper procedure of "Reporting Last Cabin". *
8	3.11.06	Observation : Advice given :	Replacement of rusty pulleys were being conducted by Leitner, with little input from Skyrail. - Closely monitor of replacement of rusty pulleys in all terminals and angle stations. - Examine if there is excessive wear of the belts and pulleys. * - Addition of tensioning device for the belts in the deceleration/acceleration systems in the terminals and angle stations. *

9	16.11.06	Observation : Advice given :	Anemometer at Tower 4 was found out of function. Restoring the proper functioning of the anemometer at Tower 4 which provides essential wind speed measurement. *
10	Early Jan 07	Observation : Advice given :	Skyrail has implemented a software management system, namely FRACAS (Failure Reporting Analysis, Corrective Action System), but not making good use of it. Skyrail to conduct regular fault analysis by using FRACAS so as to identify measures to minimize service interruption. *
11	5.1.07	Observation : Advice given :	One of the bolts for engaging/disengaging rescue drive from the bull wheel was found to be broken. The bolt was suspected to have broken earlier. Some staff noticed the defect but not reported to the management. - Develop appropriate measure for checking the disengagement of bull wheel coupling with the main shaft. * - Enhance fault recording & reporting system. *
12	March 07	Observation : Advice given :	Replacement of rusty connection pins were being conducted by Leitner, with little input from Skyrail. Remind Skyrail to closely monitor the replacement works with a view to identifying if there is any abnormality. *
13	30.4.07	Observation : Advice given :	A station roller was found with its rim seriously damaged. Investigation revealed that a mounting bolt for station roller was broken during ropeway operation. Regularly check and replace all mounting bolts for station rollers in view of observed corrosion.

35. While the ropeway operating company is responsible for the safety and reliability of the Ngong Ping ropeway, the same applies to the ropeway owner, namely the MTR Corp. Ltd. (MTRCL). In early 2007, it became evident that the performance of the Ngong Ping ropeway warranted close scrutiny from its owner. EMSD therefore compiled a paper (Appendix 4), outlining the observations derived from repeated incidents as well as its random inspections, and recommended MTRCL to conduct performance review of the ropeway, among other things.

36. Subsequently, MTRCL contracted TÜV SÜD to conduct an independent review and submit a report in May 2007 (Appendix 5). While "the reliability of the Ngong Ping ropeway during its initial operating period is considered to be in line with the best practice of comparable systems", the report outlined a number of areas that required improvement actions. Comparing to an independent audit of the ISO 9000 Quality Management System, some of those deficiencies would be classified as non-conformances.

37. Deriving from the observations by EMSD during the process of investigation of the service disruption incidents and during random inspections conducted by EMSD as described in tables 3 and 4, the overall performance concerning operation, maintenance and management of the ropeway were considered to have room for improvement.

38. The Expert Panel therefore considers that improvement is required in the following areas :

38.1 Training for operators and maintenance staff

Refresher training for the operation and maintenance staff is needed to enhance their technical know-how, and to upkeep the ropeway to maintain a highly reliable ropeway service to meet public expectation. In particular, enhancement of emergency preparedness and response to scenarios such as inclement weather, unexpected stoppages and happenings, as well as timely fault attendance and rectifications, is considered essential. Furthermore, communication, understanding and cooperation between operation team and maintenance team should be strengthened so that observations from the operation team could be reflected timely to the maintenance team, and vice versa.

38.2 Maintenance and operation procedures and work instructions

While operation and maintenance manuals are made available by the manufacturer, detailed procedures and work instructions are essential for operation and maintenance staff and should be developed to provide clear procedures and works instructions for all daily operation and maintenance routines. These documents should make cross reference to the relevant sections of the O&M manual, and shall be prepared and distributed to all staff concerned. Where appropriate, these procedures and work instructions should be written in Chinese for easy understanding by the staff. The documentation control system should be in line with the requirements of ISO 9000, or equivalent.

38.3 Spare parts and materials inventory control

The existing stock level of essential spare parts and materials should be reviewed, and a systematic inventory management system should be established by taking into account the lead time for delivery of spare parts and its consumption rate, such that adequate stock level of all spare parts/materials will be maintained. Furthermore, the keeping of spare parts at each terminal/station should be reviewed, for improving the response time to fault attendance and rectification.

38.4 Planned preventive maintenance

Planned preventive maintenance should be enhanced, as varying degrees of corrosion appeared in many parts of the system, for example brake discs, track rope, station pulleys, and cabin carriages. In addition, frequency of routine checks and maintenance to system components should be increased to avoid failure of components leading to prolonged service interruptions.

Another observation was that the average monthly running time of the ropeway system stands at 420 hours, which is higher than the ceiling of 250 hours per month recommended by the manufacturer, which used this ceiling as the basis for providing the recommended maintenance schedule. Therefore, with the increased usage, the maintenance frequency should be rescheduled in consultation with the manufacturer to take account of the increased running hours.

38.5 Quality management

As at end July 2007, there is no quality management system in place, risking inconsistency in operation and maintenance practices. This has resulted in repeated minor operation blunders and substandard quality of work in a number of occasions affecting the service reliability of the ropeway. The establishment and implementation of a structured quality management system would help ensure a safe and reliable ropeway operation.

38.6 Human resource management

Operation and maintenance staff is constantly on a 12-hour daily shift roster. On top of that, they are frequently required to work overtime, and prolonged working hours would invariably cause deterioration in the quality of work. For example, in April 2007, the total overtime of the maintenance team was 580.5 hours which resulted in having an effective 14-hour shift for each maintenance staff.

It should be pointed out that overhaul of the cabins has yet to be conducted as one of the routine activities. The manpower shortage problem of the maintenance team will become more acute when the overhaul programme of the cabins is going to start.

Since the ropeway system was put into operation in September 2006, four key personnel in the maintenance team (total of twenty-seven staff) left the company. It is considered that the retention of knowledge and skills in the maintenance team would need to be constantly reinforced.

38.7 Procurement practices

Procurement of services, tools, materials and spares has not been given priority, leading to delays in maintenance works and thus affecting the service reliability of the ropeway. Examples of long processing time for procurement are given in table 5. A review of the procurement practices is required, with management commitment and priority given to enable the maintenance team to have timely acquisition of services, tools, materials and spares. Besides, sourcing of alternative supply of spares and materials should also be explored.

Table 5

Description of Item	Processing Time	Consequence
1. Repair of CCTV at towers	Outstanding since March 07	Any deropement at towers could not be effectively monitored and checked.
2. Procurement of spare shaft of the spring-loaded station roller	Outstanding since May 07	Incident on 11.5.07 could have been avoided if the damaged shaft was replaced as the damage was observed before the incident.
3. Procurement of working platform for works at height inside stations	About 3 months	Work at height could not be effectively conducted prior to delivery of the platform.
4. Procurement of grip force tester	Outstanding for more than 6 months	Overhaul of cabins could not be carried out timely.
5. Procurement of V-belt tensioners	About 1 month	Fault recovery could not be timely conducted prior to delivery of the tensioners.

PART 3

PREREQUISITE REQUIREMENTS

FOR

RE-OPENING OF THE ROPEWAY

FOR USE BY THE PUBLIC

PART 3 - PREREQUISITE REQUIREMENTS FOR RE-OPENING OF THE ROPEWAY FOR USE BY THE PUBLIC

39. Having reviewed the falling of cabin incident on 11 June 2007, prevailing legislations, international standard and practices, inputs from independent surveyors, and also the operation and maintenance of the ropeway since September 2006, the Expert Panel recommends the following prerequisite requirements prior to the re-opening of the ropeway for use by the public :

39.1 Examination of all damaged parts of the ropeway arising from the falling incident, repair and replace where necessary, certification by the manufacturers of the respective systems/components, including:

(a) track rope by the rope manufacturer;
(b) hauling rope by the rope manufacturer;
(c) tower structure by a Registered Structural Engineer and tower alignment;
(d) replaced components on Tower 2B by the ropeway manufacturer.

39.2 Examination of the ropeway system, in accordance with regulation 20(3) of the Aerial Ropeways (Operation and Maintenance) regulations, on:

(a) all ropes, including gauging the circumference, visual examinations over the whole length and defectograph readings over the entire length of the hauling rope and track rope;
(b) the car hangers and grips, including the actuating and checking mechanisms;
(c) the sheave trains, sheaves, bushes, pins and beams located on trestles;
(d) the sheaves, bushes and pins at the incoming and outgoing trains located at stations;
(e) the main, auxiliary and stand-by drives and braking systems;
(f) all electric circuits, controls, switchgear and earthing arrangements;
(g) car door locking devices and cars for deformation, broken or loose windows and size of apertures;
(h) trestles and foundations, including torque loaded bolts on trestle heads;

(i) car carriage and rope speed synchronizing equipment; and
(j) any other apparatus, device or machinery as may be required by EMSD.

39.3 Testing and commissioning of the following parts and operation procedures of the ropeway as if it was a new build,
(a) all the cabins, including the grips, door mechanism, carriage and its rollers, and structural parts;
(b) drives, brakes, rope tensioning devices;
(c) all control systems, safety devices, sensors and alarms;
(d) cycling on and off systems, cabin conveying and storage system; and
(e) CCTV and all other monitoring systems.

39.4 Implementation of all necessary improvement measures identified by the Independent Review Report prepared by TÜV SÜD, for enhancing system reliability.

39.5 A proposal on the management, operational and maintenance organization, to outline how the new management will effectively operate the ropeway to meet the safety and reliability requirements, as well as the expectation of the public.

39.6 Implementation of a quality management system, such as ISO 9000, PAS 55, or equivalent, for the operation and maintenance of the ropeway. The system shall be put in place with necessary training for staff duly completed. Particular attention should be paid in the following areas :
(a) compilation of maintenance procedures and work instructions, operation checklists, activities log and to ensure their effective implementation;
(b) implementation of a proper spare parts stocking/inventory system; and
(c) Provision of focused, or refresher training to all competent persons, controllers, operators, and maintenance technicians, as well as for all new recruits. A training plan should also be submitted to ensure regular training will be provided for all the operation and maintenance staff.

- END -

The Expert Panel
on the Investigation of the Falling of a Cabin from the Ngong Ping Ropeway
Government of the Hong Kong Special Administrative Region
30 July 2007

Appendix 1

FORENSIC EXAMINATION RESULT

BY

THE GOVERNMENT LABORATORY

Lab. No.: ROS1759/1760

ANALYTICAL REPORT

GOVERNMENT LABORATORY
HONG KONG
7/F, Homantin Government Offices
88 Chung Hau Street, Kowloon

.....2..... c

Date : 24 July 2007

Item(s) for Examination : - Ngong Ping Skyrail
Incident happened on 11 June 2007
Identification of the grease dirt

Sample Description : - Dirt inside a plastic bag, and reference lubricant in glassware

Marks :- memo ref. (15) in EM/GL/03/10 SF11(A17)b

Received from : - Director of E&M Services

Received on : - 18 July 2007

Method Reference : - GC-MS

Date of Analysis : - 18 – 24 July 2007

RESULTS OF EXAMINATION

The dirt was found to contain hydrocarbons. Similar hydrocarbons were also found in the reference lubricant sample.

Dr. W H FUNG
Chemist

Director of E&M Services
(Attn.: William SHUM)

G.L.1

********end of report********

(15)

By Hand

MEMO

From DEMS	To Government Chemist
Ref. (15) in EM/GL/03/10 SF11(A17)b	(Attn.: Mr. FUNG)
Tel. No. 2808 3547	Your Ref. in
Fax. No. 2577 4901	Dated Fax. No. 2714 4803
Date 18 July 2007	Total Pages 1

Ngong Ping Skyrail
Incident happened on 11 June 2007
<u>Identification of the grease dirt</u>

During the investigation of the incident, we have collected some grease dirt from the cabin #21 (on the surface of the front station roller shaft). We suspect the dirt was the lubricant of the track rope of the cable car system. Therefore, I write to seek your assistance in analysing the dirt.

2. Grease lumps collected from the cabin #21 are enclosed in the attached plastic bag. A sample of the lubricant of the track rope, contained in glassware, is also attached for your reference.

3. Please note that we are liaising with the cable car company to provide information on the chemical composition of the lubricant, which shall be send to you once available.

4. This part of our wok work (Regulatory Services) is not under the Trading Fund and this request is not chargeable to the EMSD Trading Fund.

(William SHUM)
for Director of E&M Services

encl.

GOVERNMENT LABORATORY HONG KONG

Dr. W H Fung
18/7/2007

Lab. No.: ROS1761/1762

ANALYTICAL REPORT

.....2..... c

GOVERNMENT LABORATORY
HONG KONG
7/F, Homantin Government Offices
88 Chung Hau Street, Kowloon

Date : 24 July 2007

Item(s) for Examination : - Ngong Ping Skyrail
Incident happened on 11 June 2007
Identification of the grease dirt

Sample Description : - Grease dirt sample inside a plastic bag marked 3D and,
grease dirt sample inside a plastic bag marked 2U.

Marks :- memo ref. (16) in EM/GL/03/10 SF11(A17)b

Received from : - Director of E&M Services

Received on : - 19 July 2007

Method Reference : - GC-MS

Date of Analysis : - 19 – 24 July 2007

RESULTS OF EXAMINATION

The samples marked 3D and 2U respectively were found to contain hydrocarbons. Similar hydrocarbons were also found in the reference lubricant sample delivered to the Government Laboratory on 18 July 2007.

Dr. W H FUNG
Chemist

Director of E&M Services
(Attn.: William SHUM)

G.L.1

********end of report********

16

By Hand

MEMO

From DEMS	To Government Chemist
Ref. (16) in EM/GL/03/10 SF11(A17)b	(Attn.: Dr. W H FUNG)
Tel. No. 2808 3547	Your Ref. in
Fax. No. 2577 4901	Dated Fax. No.
Date 19 July 2007	Total Pages 1

Ngong Ping Skyrail
Incident happened on 11 June 2007
<u>Identification of the grease dirt</u>

Further to the memo dated 18 July 2007 of even series, we have collected additional samples of the grease dirt found on the cabin #21 with details as follows :-

(a) Samples inside the plastic bag marked with "3D" were collected from the surface of front station roller (i.e. downhill side);

(b) Samples inside the plastic bag marked with "2U" were collected from the surface of rear station (i.e. uphill side).

2. We suspect the dirt was the lubricant of the track rope of the cable car system, a sample of the lubricant of the track rope was sent to you on 18 July 2007.

3. Please assist to analyze the dirt.

9 JUL 2007

Dr. W H Fung

GOVERNMENT LABORATORY HONG KONG

(William SHUM)
for Director of E&M Services

encl.

Appendix 2

INPUT FROM PROF. DR. OPLATKA AND PROF. DR. NEJEZ

ON ANALYSIS OF BRAKE TEST ON 11 JUNE 2007,

AND

DYNAMIC BEHAVIOUR OF THE ROPES

Input to Report from the Expert Panel

Ngong Ping Skyrail Incident on 11 June 2007

Authors:
Prof. Dr. Gabor Oplatka
and
Prof. Dr. Josef Nejez,

29. July 2007

Input to Report from the Expert Panel

Ngong Ping Skyrail Incident on 11 June 2007

ordered by:

Electrical and Mechanical Services Department (EMSD)
Government of the Hong Kong Special Administration Region
3 Kai Shing Street, Kowloon, Hong Kong

ordered from:

Prof. em. Dipl.-Ing. Dr. Dr. h.c. Gabor Oplatka
Zweiackerstraße 34
8053 Zürich
SWITZERLAND

and

Univ.-Prof. Dipl.-Ing. Dr. techn. Josef Nejez
General court-appointed expert for the field of ropeways
Bruckhaufner Hauptstrasse 15
1210 Wien
AUSTRIA

Date of report: 29th July 2007
Number of pages: 16
Number of supplements: 8

Contents

Supplements:

1. Mechanical Test & Commissioning (T&C) Report
   Braking Tests – Operating Conditions (page 72)
   Attachment 5.1.2.1 with 4 diagrams
2. Final Operating & Maintenance (O&M) Manual
   Part: B) 4.7 – Service Brake
   Chapter 5.9 Brake tests (annually) (page 15 and 16)
3. Witness Statement of [redacted]
   Including: Brake test and preliminary statement
4. Witness Statement of [redacted]
5. Witness Statement of [redacted]
6. Rope Calculation
   Section II, Chapter 11 (page 161-163)
   Proof of lifting off the carriage
7. Relevant Regulations
8. List of some dynamic incidents that led to crash of a vehicle

1 Introduction

On Monday 11 June 2007 at 7:52 pm an incident occurred at the Ngong Ping Skyrail: after the closing of public operation, a cabin derailed and fell down from the line at tower 2B during brake tests.

EMSD asked the authors of this report

- to examine and identify the causes of the incident and
- to submit a report with conclusions and recommendations to the Government.

This report is based on

- the documents made available to us,
- the observations and tests on site and
- the various rounds of talks.

We can report the following findings.

Preface:

- Our report is neutral, without consideration for any interests and is based on state of the art knowledge.
- We limit our report to the technical part of the questions in connection with the events on 11. 6. 07. Legal as well as other technical problems of the ropeway are not treated.

2 Findings

2.1 Sequence of events leading to the incident

2.1.1 Brake Tests

On 11 June 2007 brake tests were conducted after close of public operation in the context of the annual survey inspections. The installation was loaded with empty cable cars over a distance of 122.4 m. The testing speed for the brake tests was 7.0 m/s.

The following kinds of braking are available:

- electrical braking,
- braking with service brake system,
- braking with emergency brake.

Service brake can be applied

- normal (deceleration 0.40 m/s^2),
- fast (deceleration 0.75 m/s^2),
- uncontrolled (equivalent to "unmodulated").

(The system of service brake – especially that it consists of two independent groups of service brakes with independent modulation units – is considered to be well known to EMSD, therefore no detailed description seems to be necessary. A complete description is provided in Final Operation & Maintenance (O&M) Manual, Part: C) 1.2: Reference Manual Electrical Equipment. According to Leitner the terms "uncontrolled" and "unmodulated" are used equivalently).

Table 1 shows the operating conditions of the brake tests, as follows:

- Column 3: as performed during the commissioning of the Ngong Ping Skyrail on 16. 5. 06, see also supplement 1,
- Column 4: as scheduled for the annual survey inspections in O+M Manual, see supplement 2,
- Column 5: as performed during the annual brake tests on 11. 6. 07, day of the incident.

Table 1: Brake Tests Operating Conditions, 122.4 m, Empty Carriers, v = 7.0 m/s, Section II only, deceleration rates (a) in m/s²

Nr.	Type of braking	16.5.06	O+M Manual	11.6.07
1.	Electrical braking by motor with „Stop"	a = 0.40	-	time: 7:21 pm a = 0.44
2.	Electrical braking by motor with „Fast Stop"	a = 0.60	-	time: 7:25 pm a = 0.56
3.	Mechanical braking by service brake, controlled, normal deceleration	a = 0.42	„Stop service brake" a = 0.40 ± 0.02	time: 7:29 pm a = 0.42
4.	Mechanical braking by service brake, controlled, fast deceleration	a = 0.74	-	-
5.	Mechanical braking by service brake, uncontrolled (1 group), normal deceleration	a = 0.80	-	
5B.1	Mechanical braking by service brake, uncontrolled (2 groups), normal deceleration	-	-	time: 7:36 pm first as at 7:39 pm (5B.2), a = 2.5 then as at 7:29 pm (3), a = 0,45
5B.2	Mechanical braking by service brake, uncontrolled (2 groups), normal deceleration	-	-	time: 7:39 pm first a = 2,5 finally a = 1,0 average a = 1,5
5C	Mechanical braking by service brake, uncontrolled, fast deceleration	n. a. (not applicable)	-	-

6.	Mechanical braking by emergency brake, controlled, normal deceleration	a = 0.40		-

Looking at the data of Table 1 and analyzing the procedure of the brake tests the following facts are remarkable:

- The first three tests of 11. 6. 07 – brake test No. 1 (7:21 pm), brake test No. 2 (7:25 pm) and brake test No. 3 (7:29 pm) – (diagrams 1, 2 and 3) produced almost identical results as the equivalent tests of 16. 5. 06.

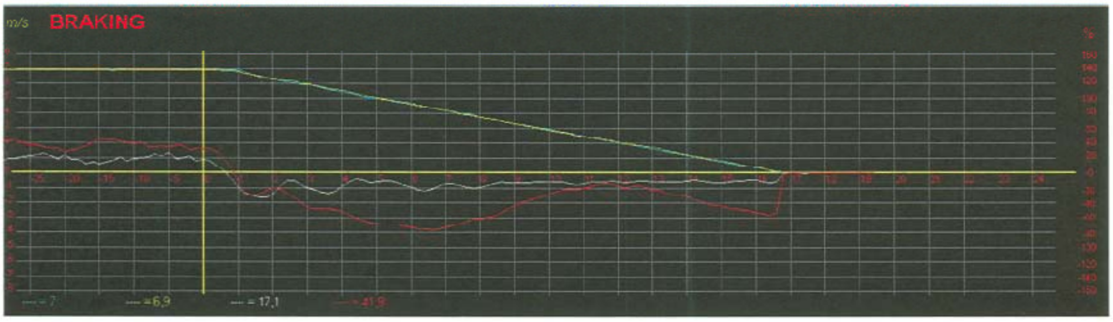


Diagram 1: Electrical braking by motor with "Stop" (brake test No. 1, 11. 6. 07)

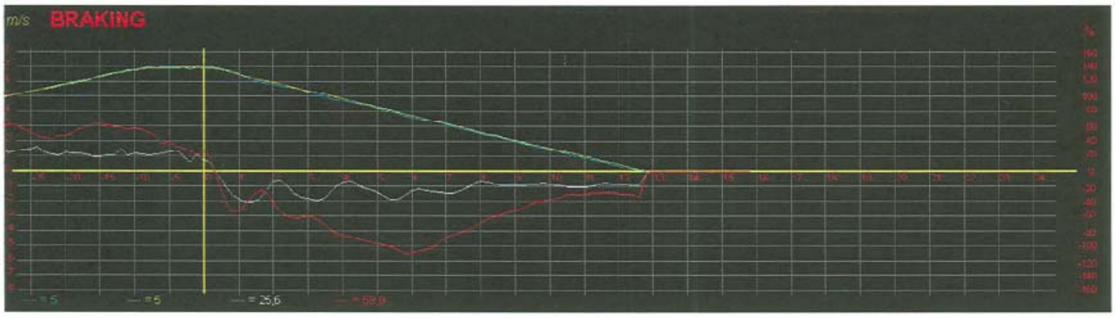


Diagram 2: Electrical braking by motor with "Fast Stop" (brake test No. 2, 11. 6. 07)

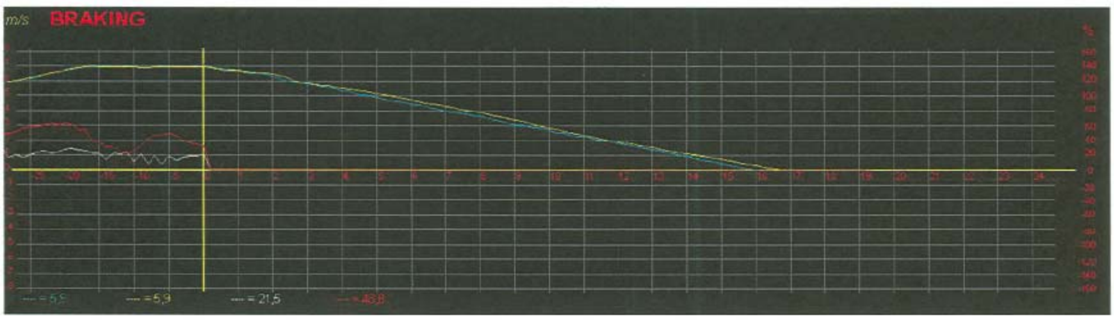


Diagram 3: Mechanical braking by service brake, controlled, normal deceleration (brake test No. 3, 11. 6. 07)

- In O+M Manual only service brake test No. 3 (7:29 pm) is required for the annual brake tests.
- Brake test No. 4 of commissioning on 16. 5. 06 was not performed on 11. 6. 07.
- At 7:36 pm an attempt was made to perform an uncontrolled service brake stop according to brake test No. 5 of commissioning (mechanical braking with service brake, uncontrolled, normal deceleration). The maintenance technician pressed four pushbuttons on the test console (Fig. 1) for an uncontrolled stop of all service brakes, but only for approximately 0.5 s – the switching cubicle had to be opened for that purpose. Therefore the initial uncontrolled braking with approximately 2.5 m/s^2 was followed by a controlled stop with linear deceleration as in brake test No. 3 (7:29 pm), with an average of approximately $a = 0.4\ m/s^2$ (see No. 5B.1 in Table 1, diagram 4).

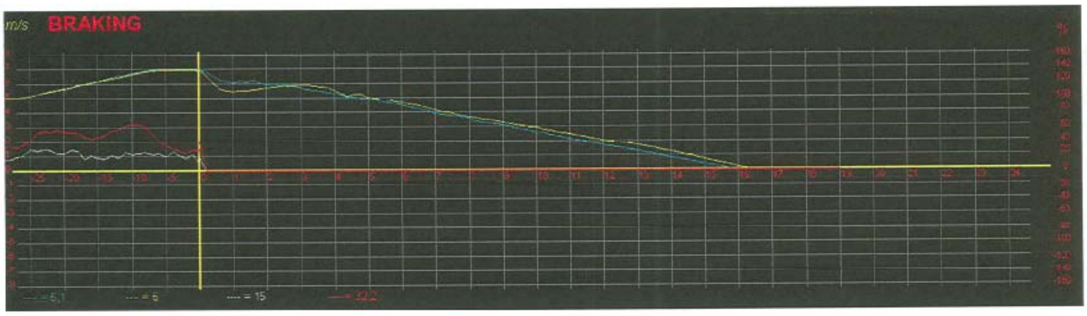


Diagram 4: Mechanical braking by service brake, uncontrolled (four pushbuttons) for approximately 0.5 s, afterwards controlled, normal deceleration (brake test No. 5B.1)

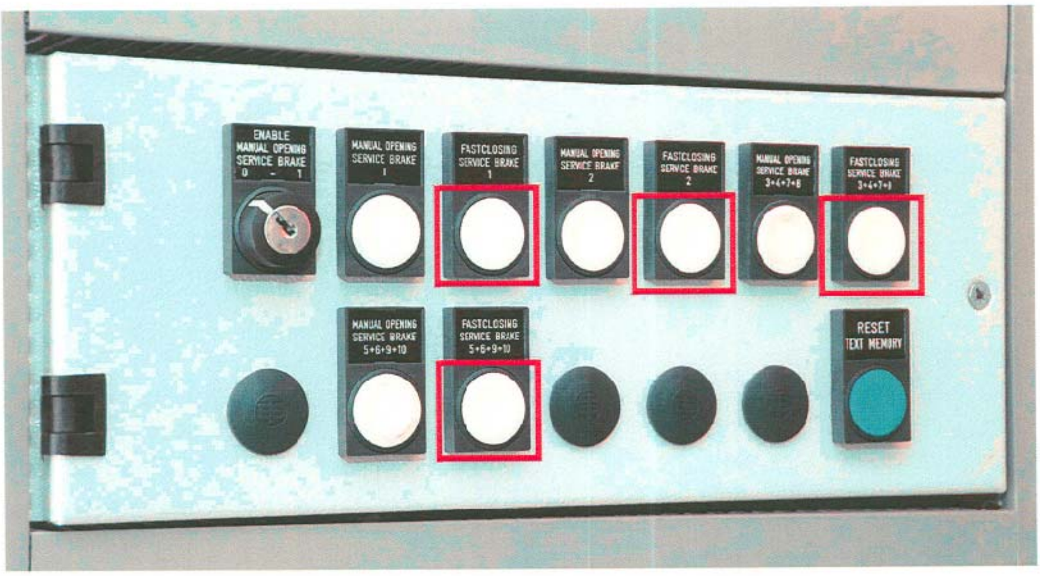


Fig. 1: Test console for service brakes inside the switching cubicle. The four buttons marked red are characterized as "FAST CLOSING SERVICE BRAKE 1", "FAST CLOSING SERVICE BRAKE 2", "FAST CLOSING SERVICE BRAKE 3+4+7+8" and "FAST CLOSING SERVICE BRAKE 5+6+9+10". The function of the pushbuttons when pressed is to close the relevant service brakes immediately without any modulation.

- Because of the low deceleration rate (0,45 m/s^2) of brake test No. 5B.1 (7:36 pm) this test was judged as invalid. Obviously nobody took care of the difference between the braking diagrams of brake test No. 3 (7:29 pm) and brake test No. 5B.1 (7:36 pm) with its high deceleration rate of approximately 2.5 m/s^2 at the beginning of the braking (see diagram 4).
- At 7:39 pm brake test No. 5B.1 was repeated but with pressing the four pushbuttons pressed during the whole braking time. This resulted in the sharpest possible braking with a braking time of approximately 5 s. The initial deceleration was 2.5 m/s^2, at the end of braking it was still 1.0 m/s^2 and on average approximately 1.5 m/s^2 (see Nr. 5B.2 in Table 1, diagram 5).

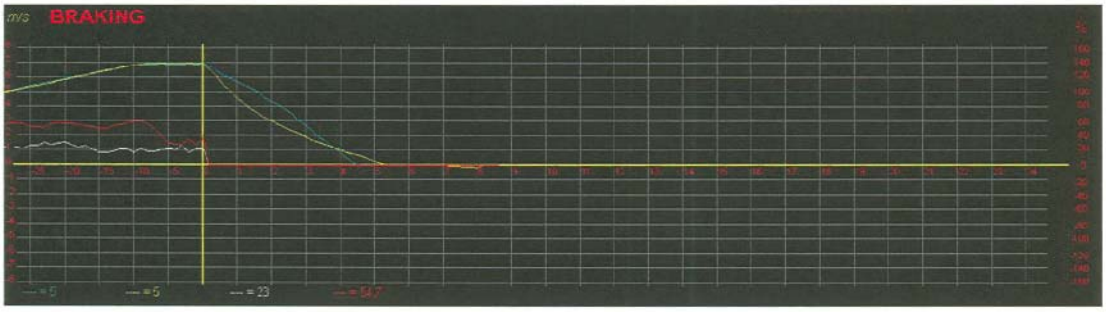


Diagram 5: Mechanical braking by service brake, uncontrolled (four pushbuttons)

- A survey of the brake tests of 11. 6. 07 of [redacted] is given in supplement 3.
- The discussions during the brake tests and the procedure after the incident following these tests are given in the witness statements. These include the above mentioned survey of the brake tests and a preliminary statement of [redacted] (see supplement 3) and the witness statement of [redacted] (see supplement 4). A witness statement of [redacted], who conducted the brake tests during commissioning is provided in supplement 5.

2.1.2 Derailment and the crash of cabin 21

The sharp braking of brake test 5 (diagram 5) caused a partial derailment of cabin 21 because of the dynamic effects emerging on both the hauling and carrying ropes. This was not observed by anybody. No grounding signal of hauling rope was observed.

Continuing the brake tests several restart attempts failed because of spatial displacements of cabins in Ngong Ping Terminal and Nei Lak Shan angle station.

The next attempt to restart the ropeway at 7:51 pm seemed to be successful. During the acceleration phase there came an automatic stop (electrical braking) at approximately 5.0 m/s, initiated from tower 2B and a grounding signal of hauling rope followed.

Searching for the cause of the stop the crash of cabin 21 at tower 2B was detected. The exact way cabin 21 failed to pass tower 2B and how it fell to the ground is of no great importance for the whole incident. Considering the evidence of the traces found and the conclusions drawn the description by [redacted] (see supplement 3) and by the "Ngong Ping 360 Incident Report" of Skyrail ITM of the way the incident happened can be accepted by and large.

3 Considerations

3.1 Why did cabin 21 get derailed?

The physical reason for the derailment of vehicle 21 was the brake test No. 5B.2 performed at 7:39 pm. The dynamic forces caused by the high deceleration of 2.5 m/s^2 led to lifting the carriage of cabin 21 off the carrying rope with the derailment following.

The input of energy caused by the high deceleration produced various dynamic effects, such as the following.

The deceleration of the hauling rope caused a series of oscillations:

- longitudinal wave in the hauling rope followed by deceleration of the vehicles,
- the deceleration of the vehicles produced a longitudinal oscillation of the vehicles
- the longitudinal oscillation of the vehicles produced a transverse wave in the carrying rope,
- the transverse wave in the carrying rope produced a vertical oscillation of the vehicles;
- the deceleration of the hauling rope also produced a transverse wave in the hauling rope,
- the transverse wave of the hauling rope produces a vertical oscillation of the vehicles.

The rope waves were reflected at the towers, at the end fixings and at the driving sheave. These could finally lead to stochastic overlays and thus to a high rate of transverse acceleration at local points of the line. The forces associated with this high acceleration were the probable cause of the derailment and subsequent crash of cabin 21.

3.2 Evaluation of brake test 5B (7:36 pm and 7:39 pm)

3.2.1 Brake tests 5B (5B.1 and 5B.2) were not indicated on the list of brake tests to be performed annually in Final O&M Manual NGONG PING 360, Part B) 4.7 – Service Brake, Chap. 5.9 Brake tests (annually), page 15 and 16 (see supplement 2).
This manual is said to have been handed out to Skyrail ITM and to EMSD by Leitner in June 2006.

3.2.2 Brake test 5B was dangerous.
This test was not performed during the commissioning of the Ngong Ping

Skyrail on 16. 5. 06. The danger could have been recognized by looking at the diagram of the brake test 5B.1 (diagram 4).

3.2.3 Brake test 5B had no recognizable technical necessity because of the following considerations:

- examination of the strength and/or efficiency (thermal capacity) of the brakes: one does not test that with empty cabins;
- examination of the correct function of the modulation of the brakes: are not tested by switching the modulation off. Incidentally, the preceding brake test No. 3 has already answered this question sufficiently;
- examination of the change of the traction resistance of the ropeway after the first year of operation: one needs a base for comparison. Brake test 5B.2 was not able to serve that goal, because it was not performed in 2006. (Conceivably for this could be a comparison of the coasting distances or the power reception, but not of a sharp braking);
- examination of the dynamic behaviour of the ropeway with strong deceleration: one would have to have instruments and observe the behaviour of the installation. (This was in fact not done. It would have been difficult to carry out in the oncoming darkness).

3.3 Was it at all intended to perform brake test 5B?

If one considers that brake tests 5B are not indicated in the list of brake tests, as shown in 3.2 above and that it was dangerous and without recognizable purpose, it is justified to ask, whether it was performed perhaps inadvertently in place of test 5. Brake tests 5 and 5B differ in that in brake test 5 the modulation is switched off in only one service brake group, while in brake test 5B the modulation units of both brake groups are switched off. In accordance with the verbal report of [redacted] of Leitner the term "uncontrolled " is used for the case with only one modulation unit switched off. Therefore when both groups of service brakes are unmodulated, this would be designated as "both groups uncontrolled ". This situation is neither intended nor desired. We did not find it in any manual supplied and not in writing anywhere.

3.4 The interplay of forces with sharp braking

3.4.1 The sensitivity of bicable uni-directional aerial ropeways to dynamic effects is an old and well-known fact. Such effects occur especially on braking. They typically cause cross-over of the hauling rope and lift empty vehicles off the carrying rope. The danger increases among other things with the operating speed, the length and slope of the spans and the rate of acceleration or deceleration. As early as 1951 Professor Czitary drew attention to this danger [1]. As far as we know accurate calculation methods exist only for monocable aerial ropeways [2] and reversible aerial ropeways [3]. The existing calculation methods for the dynamic behaviour of bicable gondolas [4, 5] are not applicable for our case. We estimate that one to two man-year work would be necessary to extend the existing methods to our application. In our case Leitner took account of the danger of lifting off by calculating the stability of the vehicles with ±50 % variation of the tension force in the hauling rope. In the case of Ngong Ping Skyrail this computation is in the Rope Calculation, Section II, Chapter 11: Proof of the lifting of the carriage (page 161-163, see supplement 6).

3.4.2 The most obvious danger during a sharp braking maneovre is that the increased hauling rope tension force will lift a(n) (empty) vehicle off the carrying rope. It is to be expected that in the case considered those vehicles are at most endangered, which are positioned after the exit from the braking station and/or on the highest point of the line. Vehicle 21 was, however, not far from the entrance to the braking station, where following a quasi-static view, a decrease of the tension force in the hauling rope was to be expected. (The reflection of the wave from the driving sheave might have been essential. How violent these longitudinal oscillations of the hauling rope were after the braking test 5B.2 in comparison with the preceding braking test (5B.1) shows the video of the monitoring camera at tower 4 and registration of the speed of the haul rope in the upper station)

3.4.3 A further dynamic effect is to be considered. If a vehicle is decelerated by the hauling rope, the cabin swings off in the driving direction because of its inertia. The carriage applies a momentarily increased normal force on the carrying rope. In the carrying rope a transverse wave is produced, which starts to run in both directions. The wave reaches the next tower and is reflected there. In our case the longitudinal speed of the wave in the carrying rope was about 200 m/s. The distance between the car and tower 2B was 173 m, i.e. the reflected wave reached the vehicle after approximately 1.7 s. During this time the vehicle implemented a half oscillation. Thus the reflection wave of the carrying rope met the vehicle in a swinging-off-position in the uphill direction (Fig. 2).

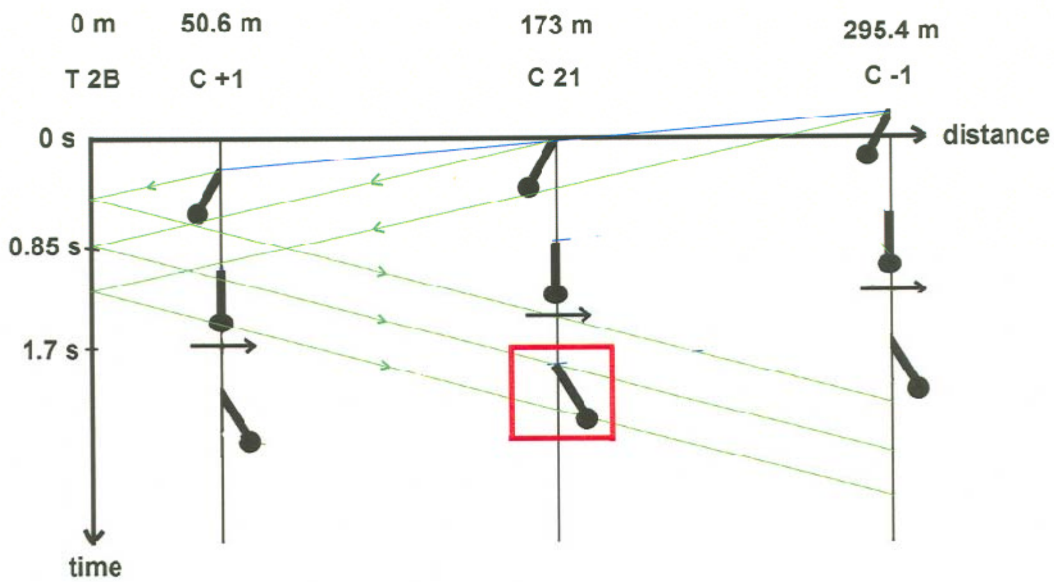


Fig. 2: The green lines show the run of the transverse waves of the carrying rope caused by the braking as described in the preceding text. The shift times for the vehicles C +1 and C -1 (blue line) are not based on computations, they show the qualitative influence only. The coincidence of the oscillation period of vehicle 21 and the running time of the wave reflected by tower 2B that meets it coincide; the reflected wave meets the vehicle at the moment, when it is in its furthest swing-off-position in the opposite direction (marked red).

Oscillation tests show that the oscillation period of the empty cabin is about 3.4 s. Therefore the cabin of vehicle 21 is in swing-off-position to the rear when the reflected wave meets the carriage. The wave has the tendency to lift off the carriage (Fig. 3). This could be the cause of derailment of cabin 21 and not any other vehicle. The lifting off must happen by lifting all four rollers simultaneously because according to tests derailment is not possible if only one half of the carriage is lifted off alternately.

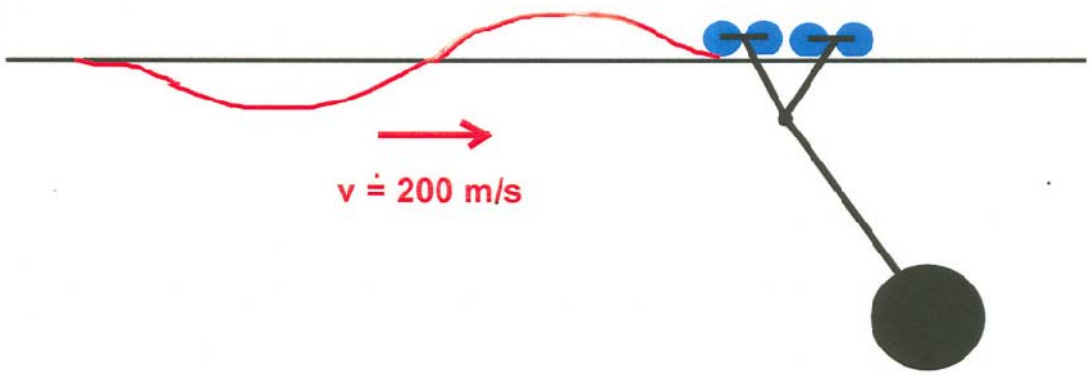


Fig. 3: If the transverse wave of the carrying rope running with approximately 200 m/s meets the carriage whilst the vehicle is in a swinging off position in the opposite direction it will tend to lift off the carriage (schematic sketch).

3.4.5 A third possible effect can take place when on sharp braking the increased friction (or blocking) in the bearing between carriage and suspension may lift the front and rear of the carriage of the swinging cabin alternately and so displace it from the carrying rope. This effect did not play any role here. The bearing of vehicle 21 under the load of the empty cabin showed on examination an insignificant bearing friction (the lower edge of the cabin stops at ±20 mm of deviation in case of the cabin moved forward and backwards with very slow back motion). On disassembling the bearing as shown in Fig. 4, it did not show any sign of rust; lubricant was present plentifully and in perfect condition.

Fig. 4: The suspension shaft was in perfect condition, more than sufficient lubricant was present.

3.4.6 The initial assumption that rope waves caused by the acceleration phase have an influence on the waves of the following braking proved as groundless. This became apparent during the measurements of dynamic behaviour at about the point of derailment (Fig. 5).

Fig. 5: Measuring assembly for the observation of the peak-to-peak swings that the ropes perform during acceleration and deceleration phases (conducted on 26. 6. 07)

3.4.7 To which extent the increasing tensioning force and the transverse waves of the hauling rope and that in the carrying rope caused the lift off of the carriage must finally be left open.

3.5 Other causes of derailing of cabin 21

There is no reason to suspect any cause for derailing of the carriage other than the sharp braking of brake test 5B.2.

- The tracks in the layer of lubricant on the carrying rope change in the range of the braking distance whereas it is constant before and behind that point. This shows that a sudden change took place in this range.
- On the carriage no deformations could be detected, that could have existed before the brake test 5B.2 and could have caused the carriage to get derailed.
- No wires exit the carrying rope that could have caused a derailing.
- A defect of tower 2B can be excluded, because the preceding vehicle passed it without problems and all the existing damage at tower 2B comes from vehicle 21 and/or from the derailed hauling rope.

4 Recomendations

Our recommendations are the following:

4.1 Concerning the staff and maintenance works:

4.1.1 Training of personnel should be improved and checked.

4.1.2 For all tests a clear operational sequence and responsibility plan should be provided.

4.1.3 All tests not contained in the O&M Manuals should be approved by the authorities and manufacturers.

4.1.4 It should be guaranteed that orders during operation, maintenance and tests are passed on clearly and safely, i.e. a clear discipline should exist during the transmission of questions and instructions. It should be guaranteed that orders are understood correctly by repeating the order by the receiver.

4.2 Concerning design

4.2.1 The dynamic behaviour of the ropeway should be reviewed with a view to improvement. In particular conditions should be noted under which significant oscillations arise.

4.2.2 Operating conditions should be examined for possible dangers, especially under deceleration. Further it should be determined which maximum possible rate of deceleration under such operating conditions should be allowed.

4.2.3 It should be guaranteed that partial derailing of a carriage stops the ropeway (e.g. by ground fault).

4.2.4 It should be assured that operations which must not be carried out at the same time are interlocked. (e.g. avoid the switching off of both modulation units of service brakes at the same time).

4.3 Concerning restart of installation:

4.3.1 All checks that are to be conducted after one year of operation should be carried out.

4.3.2 All parts of the installation that might have been damaged by the incident should be checked (especially all vehicles, towers and ropes).

4.3.3 As long as requirement 4.2.2 is not fulfilled the speed should not exceed 5,0 m/s.

4.3.4 The requirement 4.2.4 should be fulfilled before restart of installation. It is strongly recommended to fulfil requirement 4.2.3 before restart of installation, too.

4.4 Concerning the manuals:

4.4.1 It should be clarified which version of documents (e. g. T&C Report, O&M Manuals) is valid.

4.4.2 Concerning the manuals one single term should be used for the same item.

4.4.3 The term "unmodulated" or "uncontrolled" is misleading. It is not defined whether the switching off of the modulation unit of one or both groups of service brakes is understood. It should be checked whether still other misleading definitions exist. All misleading definitions should be clarified.

4.5 Additionally we recommend:

4.5.1 EMSD should participate in ITTAB meetings (Internationale Tagung der Technischen Aufsichts-Behörden = International Meeting of Supervisory Authorities of Ropeways) to get acquainted with colleagues and improve practical knowledge concerning ropeway operation and incidents.

4.5.2 The recommendations contained in "Ngong Ping 360 Incident Report" of Skyrail ITM should be examined for their relevance.

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Zürich, Wien, 29. 7. 2007

Oplatka .... (Prof. Dr. Gabor Oplatka)

J. Nejez .... (Prof. Dr. Josef Nejez)

Enclosed: 8 supplements

Supplement 1

Mechanical Test & Commissioning (T&C) Report

Braking Tests – Operating Conditions (page 72)

Attachment 5.1.2.1 with 4 diagrams

5. BRAKING TESTS

5.1. Braking Tests - Operating Conditions

Description of Works:

Braking tests shall demonstrate, that the cable car can be stopped safely within reasonable time under any load condition.

Braking tests are normally carried out repeatedly, very often with the same load condition as before. If no special precautions would be taken, the carriers would always enter the terminals / stations during braking, which would every time slightly change the carrier distance without having the chance to restore, this would further lead to problems with the safety devices. Additionally it would cause an unnecessary wear of the equipment.

In order to reduce effect from this situation (due to the many stations it is impossible to avoid it totally), loads of a certain no. of cabins is distributed in a lower no. of cabins (means overload in certain cabins), in order to avoid full loaded carriers to enter terminals / stations.

The following tests have to be carried out:

- Auto deceleration
- Normal braking with motor, normal deceleration rate
- Normal braking with motor, high deceleration rate
- Braking with modulated service brake, normal deceleration rate
- Braking with modulated service brake, high deceleration rate
- Braking with service brake but not modulated (e.g. battery is failing)
- Braking with modulated emergency brake, normal deceleration rate
- Braking with modulated emergency brake, high deceleration rate
- Braking with emergency brake but not modulated
- Braking with emergency brake using the manual lever
- Braking caused by over speed
- Braking caused by reverse direction

Location: N/A

Load Conditions:

The tests have to be carried out with the shortest (122.4 m) and longest carrier distance (238.7 m) with most unfavourable load in both uphill and downhill direction. The shortest carrier distance (**122.4 m**) is driven in section II by **2 gear units and 4 motors** while the longest carrier distance (**238.7 m**) is driven in section II by **1 gear unit and 2 motors** only, when only 13 passengers enter the cabin. Due to the rising and descending sections between TCT and NPT, the highest load occurs with a special load distribution.

Tung Chung Cable Car Project
Contract No. 5200 - Aerial Ropeway
Mechanical Part of Test & Commissioning - Record Sheets

LEITNER® ropeways

Attachment 5.1.2.1: Braking Tests Operating Conditions - 122.4 m - Empty Carriers

Name of Inspector: [redacted]   Date: 16 May 2006

Signature of Inspector: [redacted]   Witnessed by: [redacted]

Test power supply shut off ↳ braking with controlled service brake	Torque I / II [%]	Travel Distance [m]	Speed [m/s]	Braking Time [s]	Deceleration [m/s²]	Findings	
Electrical braking by **motor** with **"Stop"**	23/40	58.7/60.1	7.0	16.4/16.7	0.41/0.40	-15% } during -67% } stop	1
Electrical braking by **motor** with **"Fast Stop"**	24/29	38.7/39.6	7.0	11.0/11.1	0.61/0.60	-34% } during -123% } stop	2
Mechanical braking by **service brake, controlled, normal** deceleration	24/42	59.9/59.6	7.0	17.3/17.2	0.40	→ change parameters	→ ⊗
Mechanical braking by **service brake, controlled, fast** deceleration	22/35	32.7/32.2	7.0	9.3/8.7	0.73/0.74	✓	4
Mechanical braking by **service brake, uncontrolled, normal** deceleration	22/39	20.3/29.7	7.0	5.9/8.7	1.18/0.80	✓	5
Mechanical braking by **service brake, uncontrolled, fast** deceleration			n.a.				
Mechanical braking by **emergency brake, controlled,** normal deceleration	26/41	25.3/60.1	7.0	7.3/~~6~~ 17.3	0.94/0.40	emergency + service brake applied	6
Mechanical braking by **emergency brake, controlled,** fast deceleration							
Mechanical braking by **emergency brake, uncontrolled**				n.a.			
Mechanical braking by **emergency brake, manual valve**							
Auto-Acceleration / Deceleration							
Electrical overspeed %				separate test			
Mechanical overspeed with pendulum %		see					
Service brake controlled normal deceleration	18/47	62.2/57.6	7.2/7.0	16.6/16.2	0.39/0.42	with different control parameters	→ ⊗
Emergency brake controlled	11/45	26.5/61.9	7.0	7.5/17.4	0.91/0.39	without service brake	
Service brake controlled normal deceleration	22/52	59.6/59.2	7.0	16.4/16.6	0.40/0.41	with different control parameters	→ ⊗
⊗ — " —	15/46	57.6/58.7	7.0	16.1/16.4	0.42/0.41	final parameters	3

Diagram brake test Nr. 1:

Diagram brake test Nr. 2:

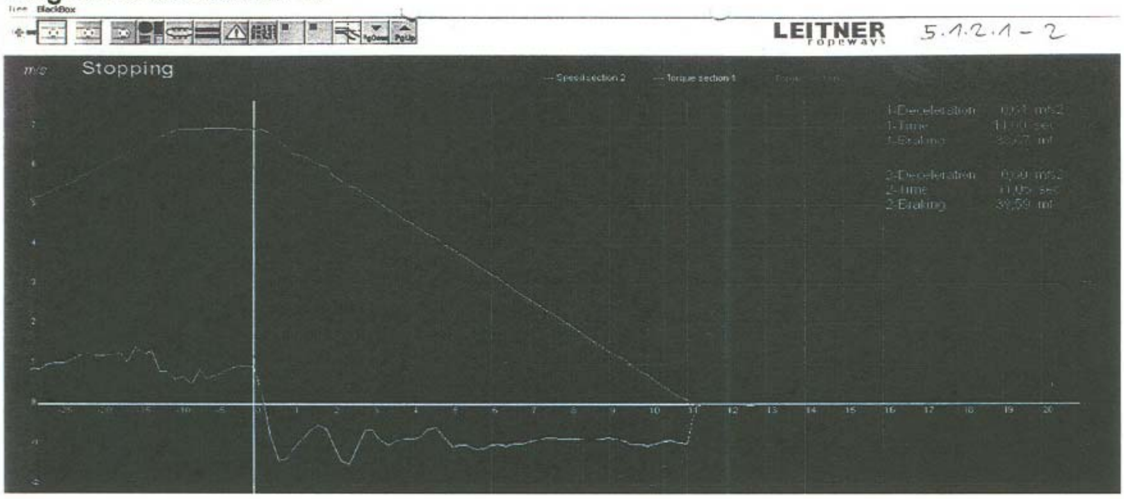


Diagram brake test Nr. 3:

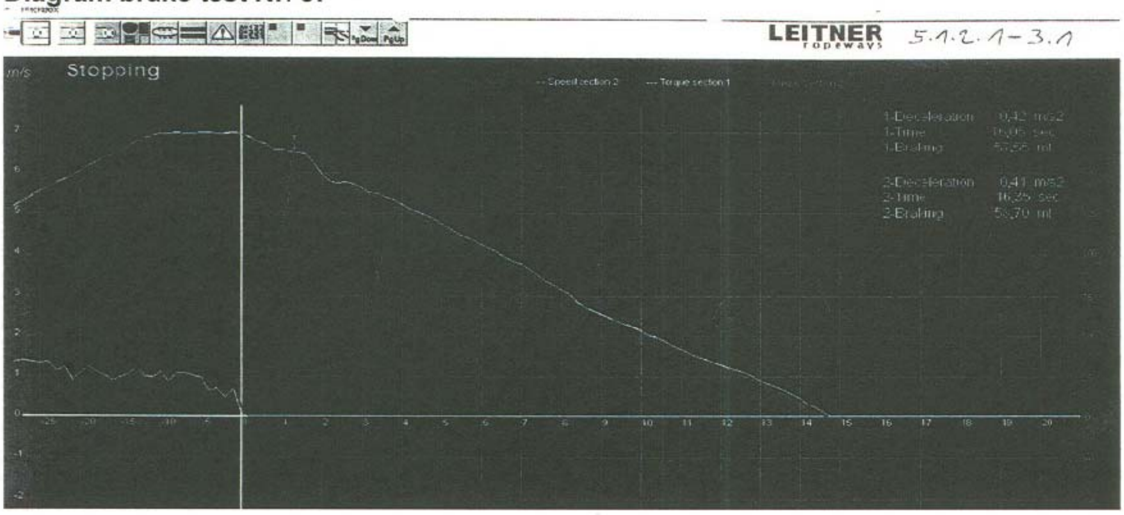


Diagram brake test Nr. 4:

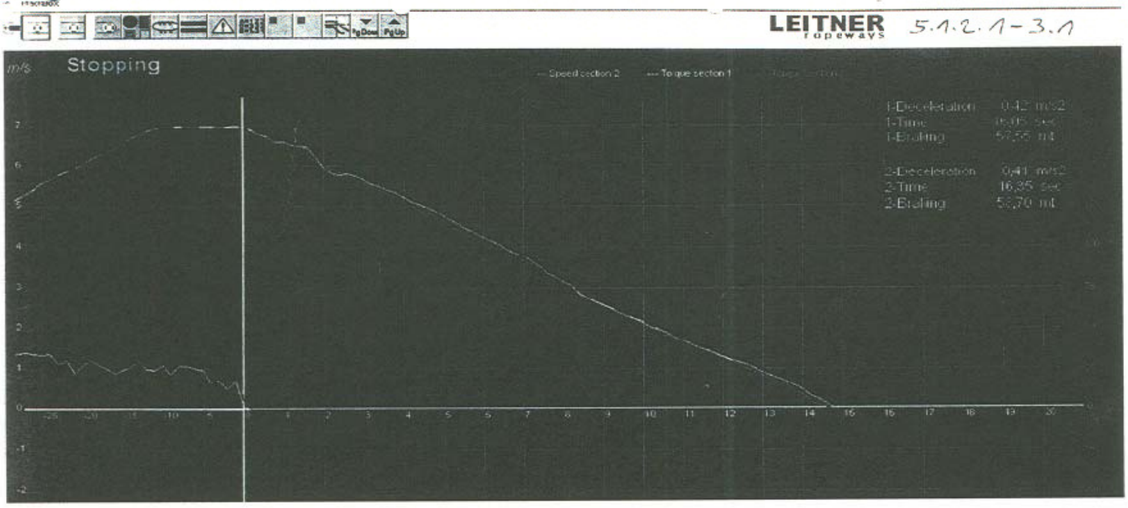


Diagram brake test Nr. 5:

Supplement 2

Final Operating & Maintenance (O&M) Manual

Part: B) 4.7 – Service Brake

Chapter 5.9 Brake tests (annually) (page 15 and 16)

5.7 Inspection of surface coating (6 months)

Careful and detailed cleaning is required in order to prevent corrosion and should therefore be carried out regularly in case of soiling.

The surface of the elements has to be inspected for the formation of rust. If required, the protective coating has to be repaired professionally.

Corroded and damaged small parts such as bolts, washers, nuts, split-pins, etc. have to be replaced.

5.8 Lubrication of spring (3,000 hours / annually)

Lubricate spring. Type of grease: see Component Manual "B) 0.5: Table of Lubricants".

5.9 Brake tests (annually)

Annual brake tests have to be carried out with

- shortest carrier distance (122.4 m / 100% transport capacity / 109 cabins on line)
- travelling speed 7 m/s

with the following load conditions:

- all cabins empty
- max. load downwards with load of 17 passengers (17x75 kg) per cabin

Reference is made to the braking tests which have to be done with the emergency brake using partly the same load conditions, those tests shall be done at the same time as the tests of the service brake. Please refer to Component Manual "B) 4.8: Emergency Brake - Mechanical Part".

5.9.1 Empty cabins

As the service brakes are normally controlled and provide a constant deceleration rate independently from the load condition (except in the range of maximum load), it is difficult for the personnel to realize any difference in brake efficiency.

In order to have the possibility to check the efficiency for any changes, instead of the deceleration rate the current of the electromagnets of the service brakes is used for evaluation.

All cabins have to be empty for the test. Start the cable car and operate with travelling speed 7 m/s. The brake test can start any time, push the red "Stop Service Brake" button in the control room of AIAS.

The service brake is acceptable, when both sections of the cable car can be stopped after a travel distance of about 60 m and a deceleration rate of about 0.4 (+/-0.02) m/s^2, the brakes were held more or less open during braking (refer to the current of the electromagnets) and the emergency brake was not applied to maintain the deceleration rate.

The diagrams showing the current of the electromagnets of the brakes section II, both for service brake 3+4+7+8 and 5+6+9+10, have to be saved on the computer, printed and compared with the diagram of the respective test during T&C, refer to the As-Built Document "C) 1.5: Test & Commissioning (T&C) Report", part "Mechanical Test & Commissioning (T&C) Report ", clause 5.1.2.1, diagrams 5.1.2.1-3.2 and -3.3, or refer to Figure 6 and 7.

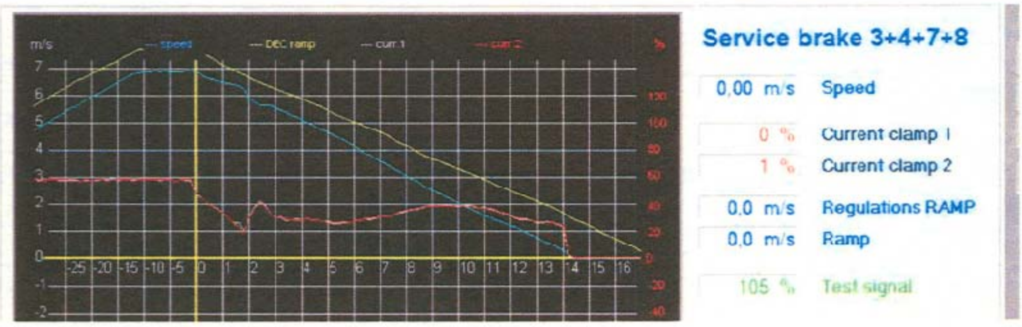


Figure 6: Diagram current of the electromagnets service brake 3+4+7+8 "Service brake controlled, normal deceleration" of T&C

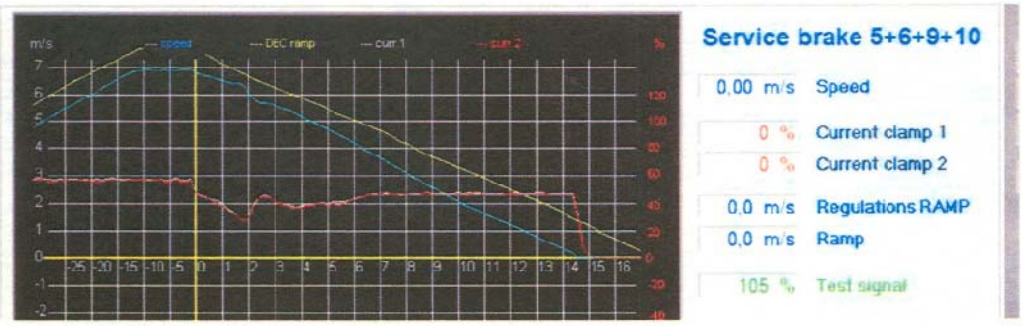


Figure 7: Diagram current of the electromagnets service brake 5+6+9+10 "Service brake controlled, normal deceleration" of T&C

WARNING!

- **If the current of the electromagnets or the brake data deviate significantly from those of the tests during T&C, contact the LEITNER company for clarification!**

Supplement 3

Witness Statement of [redacted]

Including: Brake test and preliminary statement

Supplement 4

Witness Statement of [redacted]

Supplement 5

Witness Statement of [redacted]

Supplement 6

Rope Calculation

Section II, Chapter 11 (page 161-163)

Proof of lifting off of the carriage

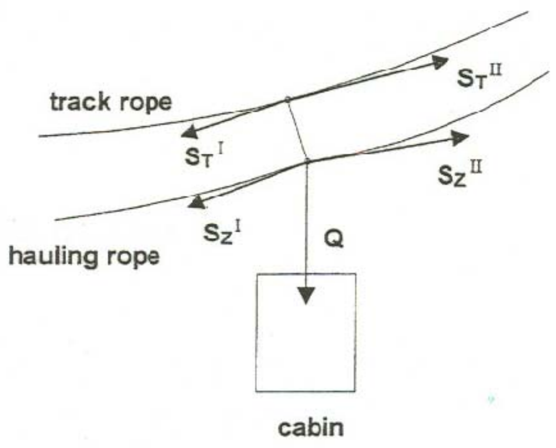
LEITNER®
Advanced Technology Worldwide

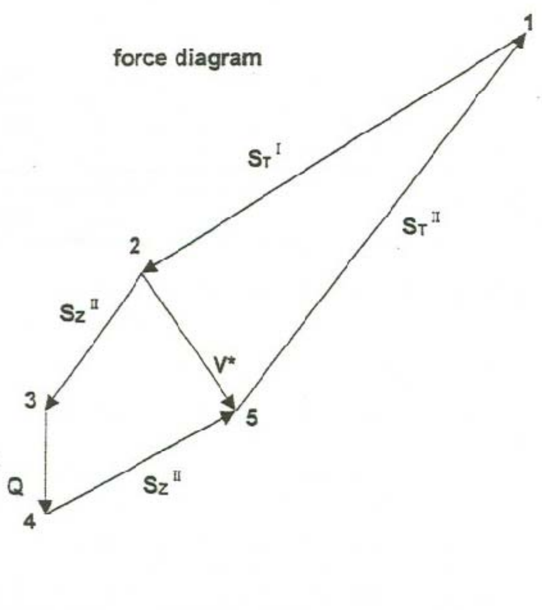
Tung Chung Cable Car Project
Contract No. 5200 - Aerial Ropeway
Rope Calculation – Section II

11. PROOF OF LIFTING OFF OF THE CARRIAGE

According to CoP it has to be proven that the carriage is not lifted off in case of increase or reduction of the hauling rope tension force by 50 %.

In a bicable ropeway the track rope has a carrying function, the hauling rope the hauling function. As far as the forces acting onto the carrier are concerned, the rope tension forces of track rope and hauling rope as well as the acting load Q have to be balanced.





According to chapter 6.6 the increase of the rope tension force of the track rope due to the carriers travelling along the different rope spans was calculated assuming an evenly distributed load. If the hauling rope tension force is increased, the hauling rope progressively takes over the carrying function from the track rope.

The decisive load case for the lifting off of the carriage is the load case with empty carriers at the distance between carriers A_{MAX} and the minimum temperature T_{MAX} since this load case has the lowest increase of track rope tension force.

In analogy to chapter 6.6 the increase of the track rope tension force due to the carriers travelling along the individual rope spans is calculated with increased or reduced hauling rope tension force. Since the lowest increase of track rope tension force results for this load case in section 3 between the Angle station and Ngong Ping Terminal and the hauling rope tension force is also great in the area of the Angle station, therefore this examination is only carried out for section 3.

11.1. *50 % increase of hauling rope tension force*

Hauling rope tension forces

Empty carriers

span	f_{mi}	S_{HH} at span centre	S_{HH} total	S_{HW} at span centre	S_{Hm} at span centre	H_H
	[m]	[kN]	[kN]	[kN]	[kN]	[kN]
9	0.91	0.4	0.7	0.2	406.0	405.3
10	34.10	-1.2	-7.1	-2.4	398.2	396.0
11	5.49	-1.0	-2.7	-0.9	391.9	389.9

Track rope tension forces

Empty carriers

span	ΔS_{Ti}	S_{Ti1}	S_{Ti2}	f_{mi}	φ_{Ti1}	φ_{Ti2}
	[kN]	[kN]	[kN]	[m]	[°]	[°]
9	8.0	995.0	997.6	0.91	2.02	4.60
10	8.0	997.6	969.3	34.10	-13.83	2.03
11	8.0	969.3	958.5	5.49	-8.97	-2.53

In spite of the 50 % increase of the hauling rope tension force the carriages of the carriers will still be supported on the track rope due to the still increased track rope tension force ΔS_{TL}, as required in the CoP.

11.2. *50 % reduction of hauling rope tension force*

Hauling rope tension forces

Empty carriers

span	f_{mi}	S_{HH} at span centre	S_{HH} total	S_{HW} at span centre	S_{Hmi} at span centre	H_H
	[m]	[kN]	[kN]	[kN]	[kN]	[kN]
9	0.98	0.4	0.7	0.2	146.0	145.7
10	36.52	-1.0	-7.1	-2.4	138.0	137.3
11	6.09	-1.0	-2.7	-0.9	131.9	131.2

Track rope tension forces

Empty carriers

span	ΔS_{Ti}	S_{Ti1}	S_{Ti2}	f_{mi}	φ_{Ti1}	φ_{Ti2}
	[kN]	[kN]	[kN]	[m]	[°]	[°]
9	177.0	1164.0	1166.6	0.98	1.92	4.70
10	177.0	1166.6	1138.3	36.52	-14.36	2.61
11	177.0	1138.3	1127.5	6.09	-9.19	-2.29

In case of a 50% reduction of hauling rope tension force the increase of the track rope tension force ΔS_{Ti} is increased due to the carriers travelling along the rope spans (see chapter 6.6.6.3), because due to the low hauling rope tension force the sag of the hauling rope between the different carriers is still greater.

Supplement 7

Relevant Regulations:
Extract: Switzerland, Bicable uni-directionl ropeways 1986 (2001)

Relevant Regulations:

(1) Switzerland, Bicable uni-directional ropeways 1986 (2001):

444 Lifting of the carriage

1. The carriages of empty vehicles on bicable uni-directional aerial ropeways must not lift off the carrying rope under the following conditions:

1.1 the highest tension in the hauling rope is raised by 40% from the highest value under monotonous movement

1.2 dynamic forces (paragraph 412.3) act on the ropeway

412.3 Under the worst case combination of the load on the ropeway and the largest brake force of the service brake (residual pressure equals zero or the loss of braking control) the following operating conditions apply:

.3.1 passengers must not be lifted from their seats

.3.2 vehicle must not touch the ground or the snow

.3.3 neither the carrying rope nor the hauling rope must be lifted from their rollers (........)

(2) CEN Ropeway Standards of Technical Committee TC 242:

Safety requirements for cableway installations designed to carry persons (relevant requirements not in details here)

Supplement 8

List of some dynamic incidents that led to crash of a vehicle

List of some dynamic incidents that led the crash of a vehicle.

(Note: For Bicable uni-directional ropeways except the third incident and this list has no claim to be completed)

1971 Spain:	Passengers swing the vehicle. The oscillating vehicle is caught on the tower and crashes.
1969 Germany:	An installation with a Ward-Leonard drive is suddenly accelerated from 1.3 m/s to 2.8 m/s. The cabin hits the carriage. The carriage is partially derailed, catches on the crest frame and crashes.
(1987 Italy):	The brakes were applied too fast (over braking) on a single rope unidirectional aerial ropeway. Five cabins each with a capacity of 6 persons crash. All brakes acted in an uncontrolled mode. Four of the five cabins were empty.
1997 Austria:	After 22 years of operation without any such problems an empty cabin is lifted off the carrying rope just as it leaves the upper station in normal operation. The reason it is lifted off is the high tension in the hauling rope. The cabin is caught on the next tower and crashes. A similar accident takes place at the same point six months later on the occasion of a brake test.

Appendix 3

INPUT FROM PROF. DR. NEJEZ

ON

THE DESIGN, OPERATION AND MAINTENANCE

AND

HOUSEKEEPING OF THE NGONG PING ROPEWAY

2nd Input to Report of Expert Panel

Ngong Ping Skyrail 360
Technical Problems

Author:

Prof. Dr. Josef Nejez

2nd Input to Report of Expert Panel

Ngong Ping Skyrail 360
Technical Problems

Requested by:

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AUSTRIA

Date of report: 22nd of July 2007
Number of pages: 6

1. Introduction

During my stay in Hong Kong in connection with the investigation of the incident of 11 June 2007 I was asked by EMSD to have a look at the ropeway and point out further technical problems, which may impair the availability and/or safety of the installation in the future. As agreed upon there was undertaken a random survey throughout the installation only. This survey is not to be considered as an investigation.

2. Findings

During the survey no defects were determined, which could at present represent a danger for the ropeway. Problems, which may impair the availability and/or safety of the installation in the future or at least affect the appearance of the ropeway, are the following:

2.1 In the course of the survey it turned out that many construction units show indications of rust, which one does not expect with a so recent installation. Figures 1 to 11 show such construction units.

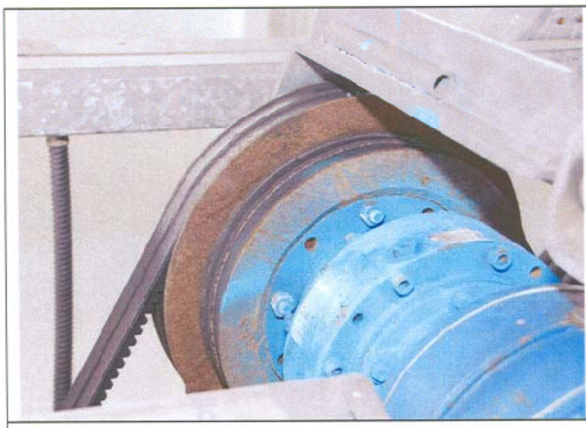

Fig. 1: Rusty V-belt pulleys at the driving motor of the conveyer systems

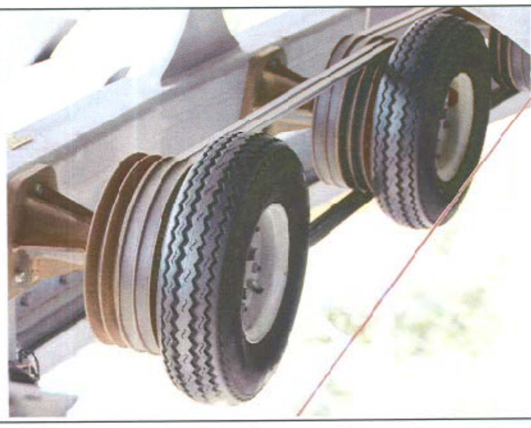

Fig. 2: Rusty V-belt pulleys at the conveyer systems

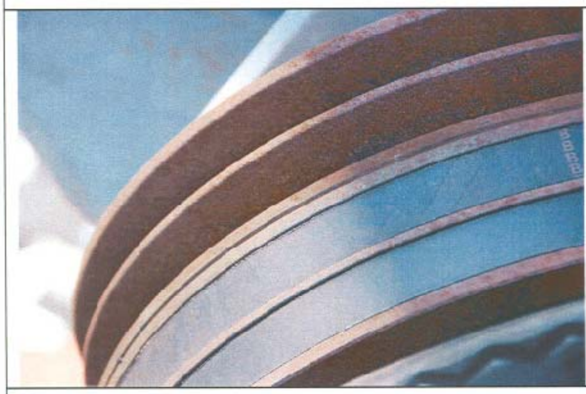

Fig. 3: Rusty V-belt pulleys at the tconveyer systems (detail)

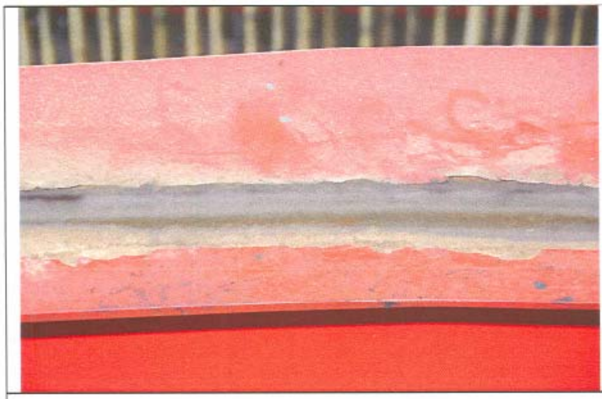

Fig. 4: Rust and peeling coat of paint at the coupling rails

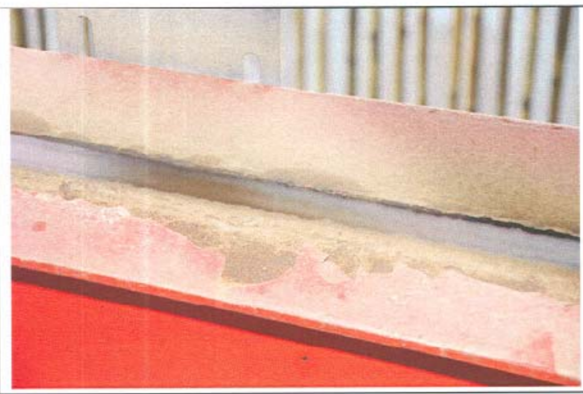

Fig. 5: likewise

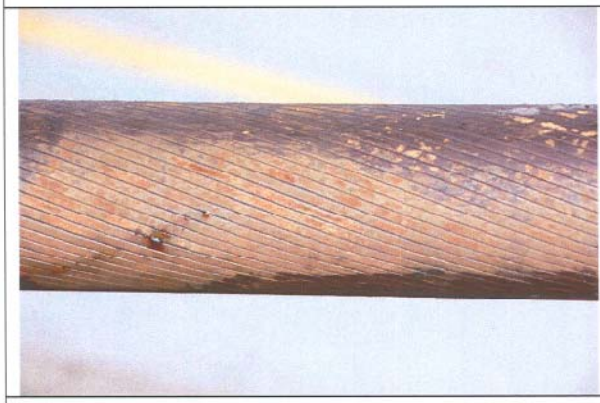

Fig. 6: Rust at the carrying rope within the range of Nei Lak Shan Angle Station

Fig. 7: likewise

Fig. 8: likewise

Fig. 9: likewise

Fig. 10: Rusty axles of the connection of suspension and cabin

Fig. 11: Even the new axles of the connection of suspension and cabin show traces of rust.

2.2 Within the range underneath the mobile platform in Tung Chung Terminal and Ngong Ping Terminal water was found, which can damage the drive of the mobile platform (electrical and mechanical parts under water). Figures 12 and 13 show that range underneath the platforms.

Fig. 12: Water within the range underneath the movable platform in Tung Chung Terminal

Fig. 13: Water within the range underneath the movable platform in Ngong Ping Terminal

2.3 On some anchor drums the outer layer of z-wires of the carrying rope show structural problems (e. g. Fig. 14 and 15). As Prof. Oplatka has told me Fatzer (manufacturer of the ropes) already took care of the problem.

Fig. 14: Structural problems of the carrying ropes in the outer layer of z-wires

Fig. 15: likewise

2.4 During the visit of the ropeway it turned out, that vehicle loading and unloading of the line takes a long time because of fault stops because of spatial displacements of cabins. It was said that because of this reason the cabins usually stay on the line during the nighttime and are not stored up in the garage in Tung Chung Terminal. This causes unnecessary stress of the vehicles and the ropes.

3. Recommendations

3.1 Rust protection should be generally improved.

3.2 The range underneath the mobile platforms in Tung Chung Terminal and Ngong Ping Terminal should be drained.

3.3 It should be clarified weather the structural problems of the carrying ropes on some of the anchor drums may cause problems in the future (e. g. at the time of relocation of the carrying ropes).

3.4 Loading and unloading procedure of the ropeway should be improved. The vehicles should usually be stored up in the garage at Tung Chung Terminal during the nighttime.

Vienna, 22nd of July 2007

J. Nejez

(Prof. Dr. Josef Nejez)

Appendix 4

PERFORMANCE REVIEW ON NP360 BY EMSD

PERFORMANCE REVIEW OF NGONG PING 360 CABLE CAR SYSTEM

Purpose

This paper reviews the performance, reliability and underlying causes of major incidents of Ngong Ping 360 (NP360) cable car system since its opening on 18 September 2006, outlines the associated findings and recommends way forward to enhance system reliability and to regain public confidence.

Background

2. There were all together 11 major incidents since the opening of NP360 for public use since 18 September 2006. These incidents have drawn intense public and media attention on the reliability of the cable car system.

The incidents

3. Among the 11 incidents, 3 were due to poor weather condition, 1 was due to inappropriate operation and maintenance and 7 were due to equipment/part failure. A summary of these incidents is given in **Annex 1**.

4. In response to these incidents, we have advised and Skyrail (the operator of NP360) has taken remedial and improvement measures including enhancement of operation and maintenance procedures, increase in manpower, better equipped with tools and spares, addition of monitoring devices and fine-tuning of the cable car system.

Areas of Concern

5. EMSD has closely monitored the progress of the remedial and improvement measures, as well as performance of the system. These measures aim to enhance system reliability and shorten the recovery time should system stoppage occur. However, it appears that some of the equipment/part failures were related to the quality of the equipment of which routine maintenance may not be able to prevent. For example, moisture was found inside the defective speed encoder that caused the stoppage incident on 3 January 2007.

6. In addition to the findings given by Skyrail in their investigation reports, our own incident investigation and on-site monitoring inspection revealed various problems in the system. For example, some of the metallic parts start getting rusty under the misty environment in North Lantau area. As these parts should have been designed to withstand local operation environment, the observed rate of deterioration and the high failure rate of components have nonetheless arouse concern.

7. Deriving from our on-site observations, a number of areas where improvement measures are required were made clear to Skyrail. A summary of the improvement measures recommended in the past and their associated progress is given in **Annex 2**. The information given in Annexes 1 and 2 indicate inadequacies in various areas and the possibility of recurrence of stoppage incident is likely. Furthermore, timely and systematic fault diagnosis is essential to efficient and speedy service recovery. However, the diagnostic software and procedure provided by the cable car manufacturer have apparently rooms for improvement. In view of the aforesaid, there is a need to review the design standard and quality of these equipment/parts with a view to enhancing overall system performance.

Recommendations

8. We are of the view that the design standard and quality of equipment, as well as the effectiveness of the diagnostic software and procedures have contributed to the repeated occurrence of incidents during the past months.

9. We recommend that an independent review of the cable car system should be conducted with regard to the following aspects :-

(a) design standard, quality and reliability of major equipment/parts and the cable car system as a whole;

(b) the current operation and maintenance management including fault prevention, recording, diagnosis and recovery procedure;

(c) performance benchmarking with overseas cable car system of similar design; and

(d) improvement measures for minimizing service interruption and thus enhancing system reliability.

10. In view of the potential risk of repeated equipment failure and hence system stoppage, we recommend the review to be completed within four weeks.

11. As MTRCL is the ultimate owner of the cable car system, it is recommended that MTRCL to engage an independent party to conduct the above-mentioned review as soon as possible.

Electrical and Mechanical Services Department
12 January 2007

Annex 1

Summary of major incidents occurred since the soft opening of NP360 for public use from 18/9/2006

Date	Impact	Stoppage Time	Cause	Underlying Problem
Sep 23, 2006	Stop boarding of passenger	10:00 – 10:15 (15 min) stop boarding of passenger, no stoppage of system	Strong wind	-
Sep 24, 2006	Stop boarding of passenger	13:24 – 13:56 (32 min) stop boarding of passenger, no stoppage of system	Strong wind	-
Sep 30, 2006	Stop boarding of passenger	9:00 – 9:39 (39 min) stop boarding of passenger, no stoppage of system	Strong wind	-
	Suspension of Service	10:35 – 11:26 (51 min) stop boarding of passenger; 10:35 – 11:13 (38 min) stoppage of system	Equipment failure (defective plug)	Operation blunder (poor engineering change management)
Oct 8, 2006	Suspension of Service	16:48 – 17:46 (58 min) stop boarding of passenger; 16:48 – 17:21 (33 min) stoppage of system	Equipment failure (insufficient clearance for haul rope)	Design imperfection
Oct 15, 2006	Service could not be started on schedule	10:00 – 11:06 (66 min) no service	Delay in maintenance work causing system not ready for operation on time	Poor operation and maintenance coordination
	Intermittent Stoppage	18:05 – 19:00 (55 min) intermittent stoppage	Equipment failure (poor contact of cable connector)	Poor design standard/ quality of component
Oct 27, 2006	Service could not be started on schedule	10:00 – 14:20 (4 hr 20 min) no service	Equipment failure (defective component on conveying system in Cabin Storage Area)	Design imperfection/ workmanship imperfection/ inappropriate torque limit setting
Nov 28, 2006	Suspension of Service	12:22 – 12:45 (23 min) stoppage of system	Equipment failure (friction belt not enough tension)	Poor maintenance strategy

Date	Impact	Stoppage Time	Cause	Reflected Problem
Jan 1, 2007	Intermittent Stoppage	16:14 – 17:26 (1 hr 12 min) stop boarding of passenger 16:29 – 16:35 (6 min) stoppage of system	Equipment failure (Air leakage on friction tire)	Poor quality of inner tube of tire and poor maintenance strategy (repeated tire failure)
Jan 3, 2007	Suspension of Service	18:20 – 19:38 (1 hr 18 min) stoppage of system	Equipment failure (Defective speed encoder)	Poor design standard/ quality of component

Annex 2

Summary of improvement items recommended and the associated progress

Date	Observation	Measures Recommended	Underlying Problem	Progress
July 31, 2006	Maintenance technician worked alone to attend fault	Strengthening of on-site supervision of maintenance activities	Poor maintenance system	Completed with satisfactory results
Aug 2, 2006	Dislocation of outer wires at the terminals of track ropes was observed	Monitoring of the condition of wire dislocation on track ropes at terminals	Inadequate awareness	On-going with close monitoring the condition via maintenance
Sep 17, 2006	Recurrence of stoppage due to "Cabin door not closed/locked" appeared	Replacement of original actuator for cabin door lock by stainless steel actuator	Poor design standard and quality of component	Completed with satisfactory results
Oct 10, 2006	The last motor speed encoder was used	Ordering of spare motor speed encoder	Poor stock management	Completed with satisfactory result
Oct 15, 2006	Proximity switch was found not function properly	Use of connector with better design standard and quality on sensors	Poor design standard and quality of component	Trial in progress
Oct 15, 2006	Recurrence of intermittent stoppage due to the activation of "Collision of Vehicle" alarm	Enhancement of operation procedures and improvement of software for controlling anti-collision alarm	Operation imperfection	Completed and performance being closely monitored
Oct 16, 2006	The last cabin with passenger was not properly reported	Reminding all controller and operators to follow the proper arrangement of "Reporting Last Cabin"	Poor operation	Completed with satisfactory result
Nov 3, 2006	A large amount of pulleys in synchronization system were found rusty after opening for use for a short period of time	Replacement of rusty pulleys	Poor design standard and quality of component	Replacement work in progress

Date	Observation	Measures Recommended	Underlying Problem	Progress
Nov 3, 2006	Excessive wear of belts and pulleys was found after opening for use for a short period of time	Study causes of excessive wear of belts and pulleys and strengthen maintenance	Poor design standard and quality of component	Study in progress while maintenance has been strengthened
Nov 3, 2006	Elongated tension belt with good condition needs replacement	Addition of tensioning device for tension belts in synchronization system	Poor design	Trial in progress
Nov 16, 2006	Malfunction of the anemometer at Tower 4 was encountered	Restoring the proper functioning of anemometer at Tower 4 due to connection problem	Poor design standard and quality of connection	Completed with satisfactory result
Jan 5, 2007	One of the three bolts for engaging/ disengaging rescue drive was found broken but was not reported/recorded	a) Replacement of bolt for engaging/ disengaging rescue drive	Poor maintenance management	Completed with satisfactory result
		b) Developing appropriate tools/gauge for checking the movement of engaging/ disengaging rescue drive	Poor maintenance system	Improvement work in progress
		c) Enhancing fault recording, reporting, tracking and analysis system	Poor maintenance system	Improvement work in progress

Appendix 5

REPORT OF THE INDEPENDENT REVIEW

CONDUCTED BY TÜV SÜD

Hong Kong

Choose certainty.
Add value.

Report

on the independent system review of
NP360 Cable Car System

Hong Kong , 30 May 2007

HK-IS /SF

Report ISR NP360 30-05-2007.doc

Date: 2007-05-30

Report no: **936 266**

Subject: Bi-cable Aerial Ropeway
Ngong Ping 360
HONG KONG

Manufacturer: Leitner GmbH

Customer: MTR Corporation Limited
MTR Tower
Telford Plaza
33 Wai Yip Street
Kowloon Bay
HONG KONG

Hong Kong

Contents

1 Introduction

At the request of MTRCL TÜV SÜD undertook an independent system review of the Ngong Ping 360 bi-cable ropeway system. The purpose of the independent system review was to provide an independent expert opinion on the performance and the reliability of the ropeway system.

The independent system review covers aspects of operation, maintenance, components and systems of the ropeway. In addition the incidents that have occurred since opening of the cableway and the corrective actions taken were assessed for appropriateness.
TÜV SÜD reviewed the operation and maintenance procedures and verified their implementation on site.

2 Findings

Based on TÜV SÜD's experiences as an authorized inspection body, the reliability of the Ngong Ping cableway during its initial operating period is considered to be in line with the best practice of comparable systems. In comparison to more than 100 ropeways for which TÜV SÜD regularly carries out approvals and annual inspections, we consider the overall operational performance of Ngong Ping 360 ropeway to be high.

The cable car system and the components are essentially suitable in terms of robustness and maintainability.

Based on our inspection on site we consider that the ropeway system and the current method of operation present no more of an operational risk than that of similar installations. The safety performance is at the same high level as similar installations and no items were found that would restrict the safe operation of the system.

NP 360 has been designed for a rope speed of 7 m/s. The examination and inspection of the cableway system by the ropeway surveyor was conducted and approved with the designed rope speed of 7 m/s prior to public operation. In completing the independent system review we found no reason that would prevent increasing the current operating speed from 5m/s to 6 or 7m/s assuming all conditions, such as wind speed, are within the limits set by the design and the related standards. Although there was no requirement for approval tests and trial operations for full speed within the scope of our review, e.g. braking tests under full load condition and evaluation of the dynamic behaviour of the ropeway under these conditions we believe it to be appropriate to incrementally increase the operating speed to allow the operating staff to get used to the increased speed.

The proposed additional weather protection device of a rain screen at Nei Lak Shan Station will protect the cableway components from direct rain but not from moisture arising from humid environmental conditions. Thus if a rain screen is installed, enhanced maintenance and improving susceptible components will still be necessary as moisture can still penetrate the station area.
As such the benefit of a partial improvement should be weighed against the investment cost.

During our inspection no major deficiencies were identified. There are however a number of minor issues that could, cumulatively impose a risk of unnecessary interruptions to public operation. These issues could benefit from improvement and although no single one would produce a step change in overall reliability together they would provide an opportunity for continuous improvement to the system over the medium to long term.

The proposed solutions and the corrective actions taken rising from the incidents that have occurred since opening to the public are considered to be appropriate.

3 Operational Review

The operational procedures are considered to be generally complete although some of these require some additional input, e.g.

- Whenever it is considered safe to bypass safety functions, substitute measures should be clearly defined which would permit the continuing operation of the cableway system by authorized operating staff under safe conditions.
- Some areas of the operation and maintenance (O&M) manual require additional detail to allow the operator to improve the procedures.
- Additional structure should be provided to the existing organizational arrangements to more clearly define the roles, responsibilities and authorisation of the operating staff.
- The Ongoing training for all operation staff should be continued to maintain and provide continuous improvement to staff.

4 Maintenance Review

The maintenance procedures are considered to be a little less developed than the operational procedures. Some of the existing procedures require additional details and input and new procedures for the maintenance activities should be established, e.g.

- Checklists should include all relevant tests and be referenced to the O&M manuals.
- More extensive checks should be undertaken to the carrier components on a daily basis.
- The procedures for disassembling components should include detailed information as necessary to allow the correct tools, materials and spares to be used, ensuring reconditioned components are suitable for operational use.
- Ongoing training for the maintenance team should continue. Specialisation of all technicians by discipline is recommended with individual skill sets detailed in a capability and competence matrix.

5 Review of Cableway System / Components

The installed cable car system generally was found to be in good condition. However, the level of corrosion in some areas arising from adverse environmental conditions was found to be higher than anticipated. Improvements and corrective actions for the enhanced protection of system components against corrosion have commenced and are being undertaken in an appropriate manner.

The main ropeway components have been inspected and verified by random spot checks and it can be stated that these components represent the state of the art and best practice of aerial ropeways.

To ensure ongoing reliability of the cableway system, attention should be given to the following

- At various locations the track rope is showing signs of surface corrosion and dislocation of a few outer layers can be seen on the de-tensioned lengths on the anchor drums. Enhanced lubrication and relocation of the outer strands of the de-tensioned section of the rope is recommended.
- The structural adequacy of the suspension support for the CCTV camera at the towers to carry the loads from vibration, wind, self weight etc. should be confirmed.
- Parts of the brake discs of the winch drives of the rescue ropeway are exhibiting surface corrosion and require cleaning/protection.
- The braking concept e.g. under which conditions the modulated and non modulated emergency brakes are activated, needs to be described.

NP360 uses the Teichmann system for the transmission of safety related signals for the cableway through the haul rope and to monitor the position of the haul rope. The monitoring requires adequate insulation of the haul rope from earthed parts.

This system is both well known and well tried and is frequently and successfully being used in similar ropeway systems. Due to the length of Ngong Ping 360 and the numerous contact points between the haul rope and earth through rollers, carrier grips, deflection sheaves in the stations etc. the complete insulation of the entire haul rope is very difficult to achieve especially under damp and humid conditions. The measures currently being taken by the manufacturer to detect and eliminate possible earth leakage paths together with enhanced cleaning of contact points are considered appropriate.

We consider the Teichmann system in general as suitable for use in the installed ropeway system under the environmental conditions of Hong Kong. To enhance the reliability and efficiency of the system the insulation for the haul rope should continue to be improved as far as is possible.

The initial problems associated with the carrier storage system in the Tung Chung Terminal have already been identified by the manufacturer Leitner. Their proposed actions of certain component replacement improvements to both the control and diagnostics of the conveyance system and enhanced recovery procedures are considered suitable measures to increase reliability.

Hong Kong

6 Summary

The independent system review concludes that the components and ropeway systems of Ngong Ping 360 are considered essentially suitable to operate in the Hong Kong environment and represent the state of the art.

Both the reliability and availability of the cableway system, as compared to other similar installations, are considered to be high.

Based on our inspection on site we consider that the safety performance of the cableway is at the same high level as other comparable systems.

The ability to keep the current performance at this high level will be dependent on the continuing development of the capability and competence of the maintenance and operations staff. In order to ensure that this is achieved, it is recommended that the capability and competences of the maintenance and the operation staff continue to be enhanced.

Identified weak components of the cableway system should be replaced or improved as discussed with the manufacturer and operator and it is recommended that all identified actions be followed up in order to further enhance the system performance.

TÜV SÜD Hong Kong
Industry Service
Chief engineer

Seyfried

TÜV SÜD Industrie Service GmbH
Department of Ropeways
Chief engineer

Disl