TOURISM COMMISSION 旅遊事務署

香港添馬
添美道二號
政府總部西翼二十二樓

Government Secretariat
22/F, West Wing,
Central Government Offices
2 Tim Mei Avenue
Tamar, Hong Kong

本函檔號 Our Ref. :
來函檔號 Your Ref. :

電話號碼 Tel. No.: 2810 2087
傳真號碼 Fax No.: 2121 1468

5 April 2012

Mr Derek LO
Clerk to Panel on Economic Development
Legislative Council Secretariat
Legislative Council Complex
1 Legislative Council Road
Central, Hong Kong

Dear Mr LO,

Panel on Economic Development

Follow-up to the meeting on 27 February 2012
"Breakdown of Ngong Ping 360 ropeway occurring in December 2011 and January 2012"

We write further to our letter of 22 March 2012 providing supplementary information requested by Members, as a follow-up to the captioned Panel meeting. We also undertook, after the Electrical and Mechanical Services Department (EMSD)'s completion of the investigation into the Ngong Ping 360 cable car incident on 25 January 2012, to submit the relevant report to Members for reference.

The EMSD has now completed the relevant investigation. The report provided by EMSD is at Annex 1, which has also been uploaded onto EMSD's website. Besides, the Ngong Ping 360 Limited has provided its

investigation summary report and mitigation measures on the incident at Annex 2. Please forward the aforementioned supplementary information to the Panel for reference.

Yours sincerely,

(Mrs Miranda YIM)
for Secretary for Commerce and Economic Development

c.c.

PSCIT

AA/SCED

Press Secy/SCED

ISD(Attn: PIO(CIT))

SEO(POO)

DEMS (Attn: Mr Harry Lai, Assistant Director/Gas & Gen Legislation)

Mr Wilson Shao, Managing Director, Ngong Ping 360 Ltd.

Annex 1

Ngong Ping 360 Ropeway

Incident occurred on 25 January 2012

Report of Investigation

Electrical and Mechanical Services Department
3 April 2012

CONTENTS

Ngong Ping 360 Ropeway
Incident occurred on 25 January 2012
Executive Summary of the Report of Investigation

1. Introduction

The Electrical and Mechanical Services Department (EMSD) conducted an independent investigation on the stoppage incident of the Ngong Ping 360 Ropeway (the Ropeway) on 25 January 2012 with a view to identifying the root causes of the incident and recommending enhancement measures to prevent recurrence of similar incident.

2. Approach of Investigation

The approach of the investigation is outlined as follows :

(i) To inspect, check and analyse the ropeway components that were involved in the incident, in particular the return bull wheel No.4, its bearings and linings ;

(ii) to conduct examination and specific laboratory tests on the bearings of return bull wheel No. 4 with support from an independent expert ; and subsequent to the finding of spalling on the upper bearing of return bull wheel No. 4, all other 6 bull wheel bearings of the Ropeway were examined ;

(iii) To carry out grease analysis of the bearings of all the 7 bull wheels with support from the independent expert in (ii) above ;

(iv) To review and analyse relevant records, in particular the maintenance records and fault log records of the concerned components, with an aim of ascertaining if the operation, repair and maintenance of the Ropeway were in order ;

(v) To check on-site some critical maintenance works performed by Ngong Ping 360 to ascertain if the maintenance works were handled in accordance with the operation and maintenance manuals of the ropeway system ; and

(vi) To interview and collect statements from 14 staff members of Ngong Ping 360 to collect the details and sequence of events before and after the incident

and on maintenance works of concerned components.

3. Background of the Incident

3.1 Abnormal noise near bull wheels No. 3 and No. 4 was first detected at around 1:45 pm by two technicians stationed at the Airport Island Angle Station (AIAS) during their patrol inspection.

3.2 The technicians located the source of the abnormal noise at around 2:00 pm and reported to their supervisor at 2:12 pm. The Assistant Maintenance Manager, Duty Maintenance Supervisor and Competent Person arrived at the scene during 2:18 to 2:35 pm to diagnose the problem.

3.3 While the Competent Person and Duty Maintenance Supervisor were conducting investigation of the causes of the abnormal noise, the Ropeway was completely stopped at 2:49 pm as a result of the triggering of the position sensor at bull wheel No.4.

3.4 After further checking and greasing of the bearings, the operation of the Ropeway was resumed at 3:22 pm with reduced speed (1 to 2 m/s as compared to the normal speed of 5 m/s) for evacuation of some 800 onboard passengers. The evacuation exercise took 91 minutes and was completed at 4:53 pm.

4. Incident Handling and Reporting

4.1 According to the investigation, the Competent Person made the “stop boarding” instruction to the Duty Controller at nearly the same time as the position sensor was triggered. If the decision to stop boarding had been made earlier, less passengers would have been affected and the evacuation time would be shortened.

4.2 The Duty Controller verbally informed the EMSD of the incident by phone at about 3:40 pm (i.e. around 51 minutes after the Ropeway was stopped). Such reporting deviated from the requirements of the established reporting

mechanism in which verbal notification should be made to EMSD within 30 minutes for any system stoppage of more than 15 minutes.

5. Causes of Incident

5.1 The incident occurred on 25 January 2012 at Ngong Ping 360 was caused by the triggering of the position sensor of return bull wheel No. 4 at the AIAS as a result of the vibration of the bull wheel.

5.2 Two factors contributed to the vibration of bull wheel. One factor was the spalling of the upper bearing of bull wheel No. 4 which was likely caused by ineffective lubrication. The other factor was the vibration of the haul rope between bull wheels No. 3 and No. 4 which was likely caused by uneven wear of lining and out-of-roundness of bull wheel No. 4.

6. Lining of Bull Wheel No. 4

6.1 The measurement record of Ngong Ping 360 revealed that the last routine measurement of the lining was conducted on 23 January 2012, i.e. 2 days before the incident. There were 3 out of a total of 12 measurement points marginally exceeding the wear limit. According to the established practice, Ngong Ping 360 had arranged the replacement of the lining but the replacement was yet to be done before the occurrence of the incident on 25 January 2012.

6.2 The on-site measurement of the lining of the bull wheel No. 4 after the incident showed that about 45% of the lining (39 out of 87 lining units) already exceeded the wear limit. Uneven worn out of the lining was found.

6.3 Spalling was found in the bearings of the bull wheel No. 4 and resulted in the unsmooth rotation of the bull wheel. This unsmooth rotation would lead to intermittent stretching and releasing of the haul rope which caused the uneven worn out of the lining and out-of-roundness of the bull wheel. Subsequently, vibration was induced to the haul rope and thus the bull wheel.

7. Bearings of Bull Wheel No. 4

7.1 Results of bearings examination revealed that :

- The spalling only occurred in the upper bearing ;
- For the inner ring of the upper bearing, brown staining from corrosion was found at the bottom raceway at the low loaded side while heavy spalling was found at the top raceway at the high loaded side ;
- In addition to spalling, heavy denting was found on the upper rollers of the upper bearing, as might be expected with the spalled metal fragments and the denting on the upper race; and
- Corrosion/rust was also observed on the outer ring between the upper and lower rollers.

7.2 The spalling of the upper bearing of bull wheel No. 4 was mainly caused by ineffective lubrication, arising from high moisture content in the grease leading to degraded lubricating effectiveness. Ngong Ping 360 has not taken sufficient precautions to preserve the unused grease against the moisture of ambient environment.

7.3 The vibration monitoring arrangement for the bull wheel was not able to provide early warning of the failure of bearings for bull wheel No. 4. The measuring interval currently adopted for vibration monitoring is not adequate for Ngong Ping 360 to ensure early identification of defects on the bearings and their timely replacement.

8. Remedial Actions and Enhancement Measures undertaken by Ngong Ping 360

8.1 To prevent recurrence of similar incidents, Ngong Ping 360 has implemented the following remedial and enhancement measures recommended by EMSD , before the resumption of cable car operation:

(i) Replace all bull wheel bearings ;

(ii) Enhance the vibration monitoring system of all bull wheels bearings to capture data on an on-going basis and examine the collected data every two weeks ;

(iii) Conduct monthly grease analysis to monitor the moisture and metal

content of the lubricating grease and step up the re-greasing frequency according to the result ;

(iv) Store and handle lubricating grease properly to prevent ingress of moisture ;

(v) Check and re-grease all bearings of the ropeway system ;

(vi) Review and tighten the procedure for inspection and replacement of the bull wheel linings.

8.2 Apart from the above immediate actions undertaken, Ngong Ping 360 has taken the following enhancement measures to further improve the reliability of the Ropeway and the overall performance in incident handling and reporting:

(i) Conduct a comprehensive review of the maintenance regime of the cable car system and complete the actions items identified ;

(ii) Enhance the emergency handling procedures and incident reporting mechanism, and provide staff with regular training to ensure their quick response to handle abnormal situations ; and

(iii) Carry out annual examination of the cable car system with satisfactory result.

8.3 Most of the measures are of recurrent nature, requiring the staff of Ngong Ping 360 to discharge them in a professional and diligent manner under close and thorough supervision of its management team. Regular examination by external auditor on the compliance of the remedial actions and enhancement measures are deemed necessary. EMSD will continue to keep close monitoring on the operation and maintenance of the Ropeway to ensure the safe operation of the Ropeway.

Ngong Ping 360 Ropeway
Incident occurred on 25 January 2012
Report of Investigation

1. Objectives

1.1 This report presents the results of the investigation by the Electrical and Mechanical Services Department (EMSD) on the stoppage incident of the Ngong Ping 360 Ropeway (the Ropeway) on 25 January 2012, and the remedial actions and enhancement measures which Ngong Ping 360 has to put in place in order to prevent the re-occurrence of similar incident.

1.2 Progress of the remedial actions and enhancement measures taken by Ngong Ping 360 before resumption of service to improve the reliability of the Ropeway is also given in this report.

1.3 Noting that there is concern from the public regarding the three service interruption incidents of the Ropeway occurred in December 2011, findings about the three incidents and the associated improvement measures are given in this report.

2. Background of the Incident on 25 January 2012

2.1 On 25 January 2012, the service of the Ngong Ping 360 Ropeway was suspended due to triggering of the position sensor of bull wheel No. 4 at the Airport Island Angle Station (AIAS) at 2:49 pm.

2.2 After the stoppage, the Competent Person of Ngong Ping 360 decided to commence the line clearance. Cable car operation was resumed after 33 minutes at reduced speed for line clearance.

2.3 The line clearance was completed at 4:53 pm on the same day and all passengers were safely transported back to Tung Chung and Ngong Ping Terminals. No injury of passengers was reported resulting from the incident.

2.4 The sequence of events of the incident determined by analysing the statements of the relevant staff of Ngong Ping 360 and other relevant records collected is listed in Appendix 1.

3. Approach of Investigation

3.1 EMSD conducted an independent investigation with a view to identifying the root causes of the incident and recommending enhancement measures to prevent recurrence of similar incident.

3.2 The approach of the investigation is outlined as follows:

(i) to inspect, check and analyse the ropeway components that were involved in the incident, in particular the return bull wheel No.4, its bearings and linings ;

(ii) to conduct examination and specific laboratory tests on the bearings of return bull wheel No. 4 with support from an independent expert ; and subsequent to the finding of spalling on the upper bearing of return bull wheel No. 4, all other 6 bull wheel bearings of the Ropeway were examined ;

(iii) to carry out grease analysis of the bearings of all the 7 bull wheels with support from the independent expert in (ii) above ;

(iv) to review and analyse relevant records, in particular the maintenance records and fault log records of the concerned components, with an aim of ascertaining if the operation, repair and maintenance of the Ropeway were in order (the list of documents examined during the investigation is given in Appendix 2) ;

(v) to check on-site some critical maintenance works performed by Ngong Ping 360 to ascertain if the maintenance works were handled in accordance with the operation and maintenance manuals of the ropeway system ; and

(vi) to interview and collect statements from 14 staff members of Ngong Ping 360 to collect details and sequence of events before and after the incident and on maintenance works of concerned components. The 14 staff members who had been interviewed and provided written statements included Competent Person, Assistant Maintenance Managers, Maintenance Supervisors, Operators and Technicians.

4. Technical Information of Ngong Ping 360 Ropeway System

4.1 The Ropeway is an aerial ropeway of bi-cable design, which employs two types of ropes, namely the track rope and the hauling rope, to perform their distinctive functions in the operation.

4.2 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.

4.3 The hauling rope is a moving rope of nominal diameter 42 mm and is below the track rope. Its function is to pull the cabin to travel along the track rope through a detachable grip. This grip will be automatically opened when the cabin arrives at the terminals, 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.

4.4 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 intermediate towers, numbered as 1, 2A, 2B, 3, 4, 5, 6 and 7, with the number 1 tower closest to Tung Chung Terminal.

4.5 The overall route length of the Ropeway is 5.7 km and it is divided into two sections, each has its own driving units, braking system, and separate rope systems for the cabins :

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

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

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

4.7 A total of 7 nos. of bull wheels, sizing from 3.4 m to 4.492 m in diameter, are

used to drive and guide the haul ropes in Section I and Section II. Two bearings (upper and lower) (see Figure 1) are used in each bull wheel to connect the bull wheel to its shaft. Among the numerous protective devices (more than 1,000) installed to ensure safe operation of the Ropeway, position sensor is installed adjacent to each bull wheel to stop the ropeway operation when there is any abnormal vibration in any of the bull wheels. A schematic diagram of the Ropeway is given in Figure 2 below.

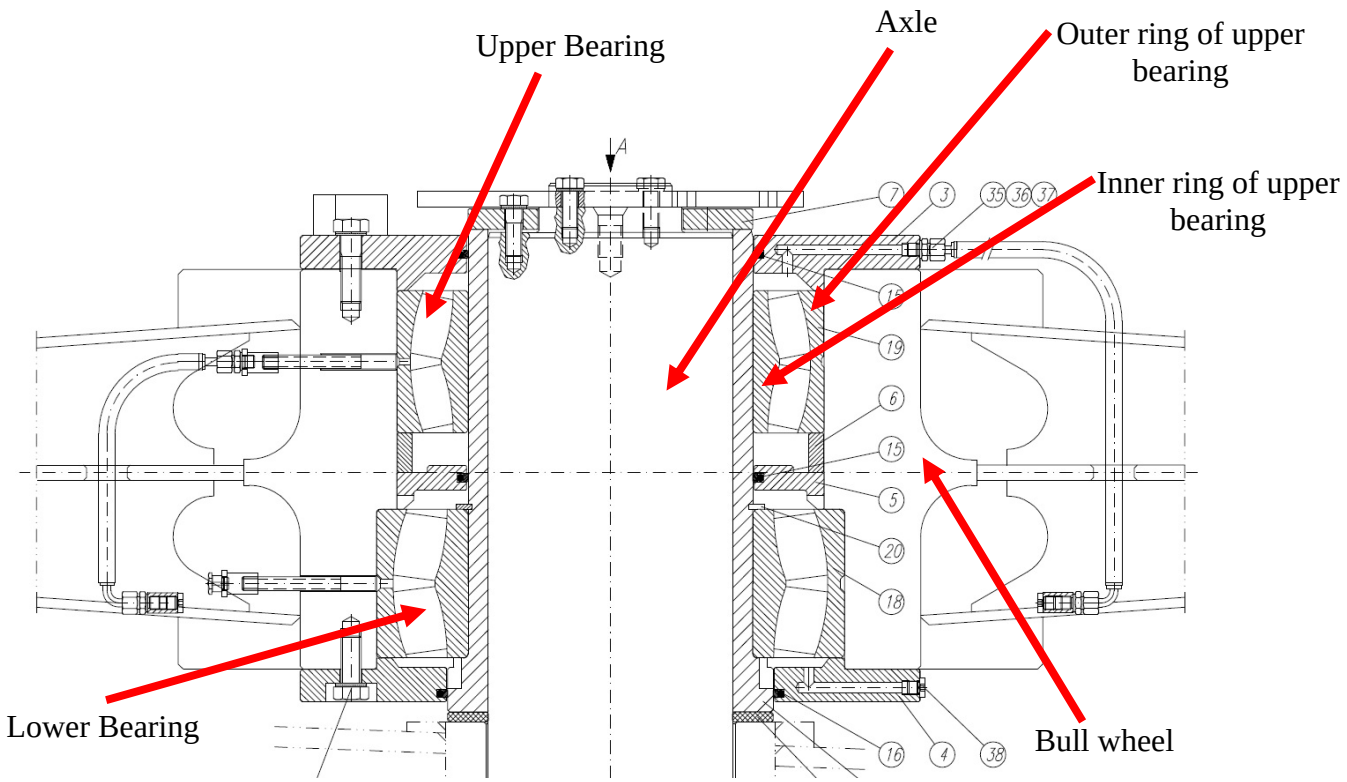

Figure 1 : Configuration of a typical bull wheel of the Ngong Ping 360 Ropeway

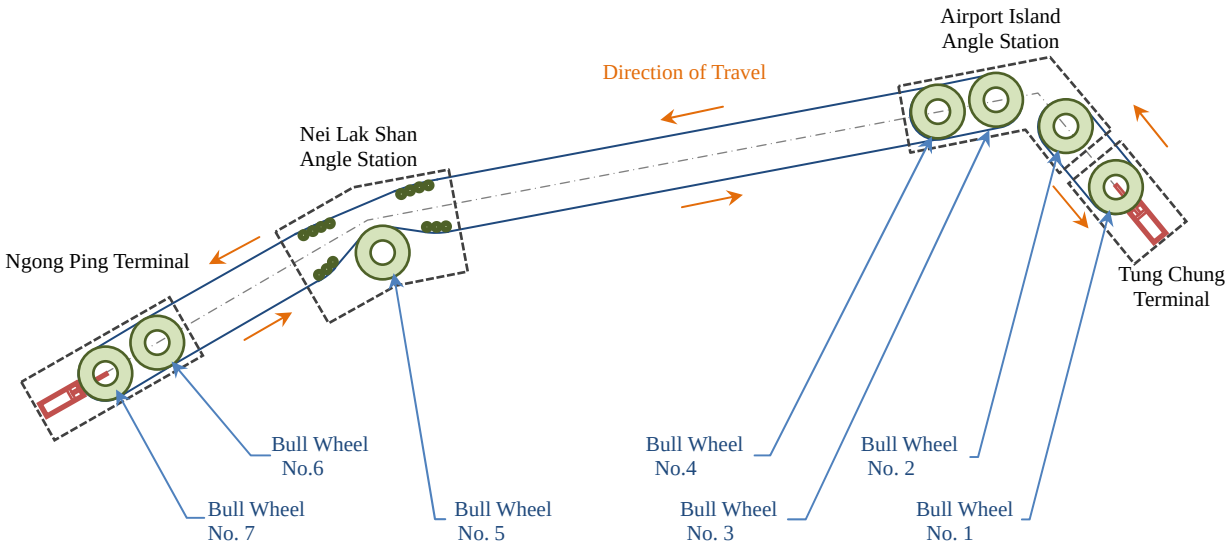

Figure 2 : Schematic diagram of the Ngong Ping 360 Ropeway

5. Observations and Findings

Incident Handling and Reporting

5.1 According to the statements collected from the staff of Ngong Ping 360, abnormal noise near bull wheels No. 3 and No. 4 was first detected at around 1:45 pm by two technicians stationed at the AIAS during their patrol inspection. The technicians located the source of the abnormal noise at around 2:00 pm and reported to their supervisor at 2:12 pm. The Assistant Maintenance Manager, Duty Maintenance Supervisor and Competent Person arrived at the scene during 2:18 to 2:35 pm to diagnose the problem.

5.2 While the Competent Person and Duty Maintenance Supervisor were conducting investigation of the causes of the abnormal noise, the Ropeway was completely stopped at 2:49 pm as a result of the triggering of the position sensor at bull wheel No.4.

5.3 After further checking and greasing of the bearings, the operation of the Ropeway was resumed at 3:22 pm with reduced speed (1 to 2 m/s as compared to the normal speed of 5 m/s) for evacuation of some 800 onboard passengers. The evacuation exercise took 91 minutes and was completed at 4:53 pm.

5.4 According to the information provided by the Competent Person, he made the “stop boarding” instruction to the Duty Controller at nearly the same time as the position

sensor was triggered. If the decision to stop boarding had been made earlier, less passengers would have been affected and the evacuation time would be shortened.

5.5 The Duty Controller verbally informed EMSD of the incident by phone at about 3:40 pm (i.e. around 51 minutes after the Ropeway was stopped). Such reporting deviated from the requirements of the established reporting mechanism in which verbal notification should be made to EMSD within 30 minutes for any system stoppage of more than 15 minutes.

Causes of Triggering of Position Sensor

5.6 According to the statements provided by the Competent Person, vigorous vibration of the haul rope between bull wheels No. 3 and No. 4 (see configuration of the haul rope at Figure 3) was observed along with the abnormal noise before triggering of the position sensor of bull wheel No. 4. The triggering of the position sensor was attributed to the vigorous vibration of the bull wheel No. 4.

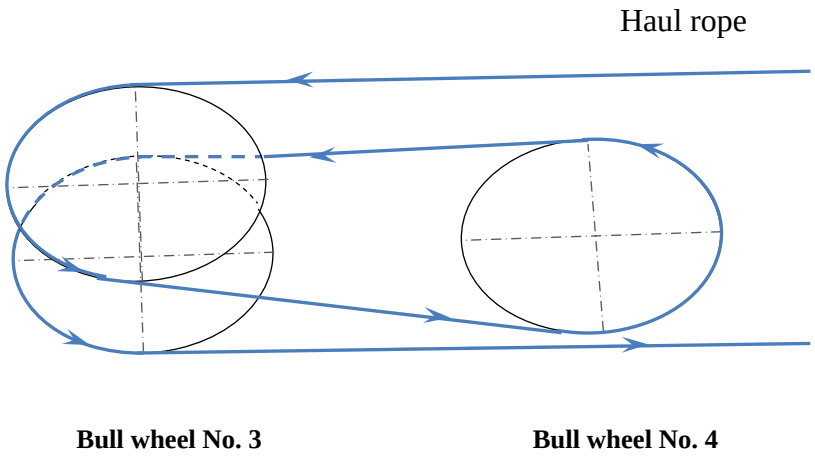

Figure 3 : Haul rope winding between the bull wheel No. 3 and bull wheel No. 4

5.7 The concerned bearings of the bull wheel No. 4 were completely dismantled for detailed examination. Laboratory tests were conducted for the metallurgical failure analysis of the bearings. Detailed measurements of the lining to ascertain the extent of wear and tear were also conducted. The examinations revealed that the following two abnormalities should be the factors contributing to the vibration of the bull wheel No. 4 which then triggered the position sensor to stop the ropeway operation :

(i) Uneven wear of the lining of bull wheel No. 4 ; and

(ii) Spalling of the upper bearing of bull wheel No. 4.

Lining of the Bull Wheel No. 4

5.8 Lining is pressed in the bull wheel as a cushion between the bull wheels and the ropes (see Figure 4), and is subject to normal wear and tear. There are two types of lining materials used in the Ropeway - plastic and rubber. It is an established practice to have the lining measured regularly so that any worn-out lining could be replaced once they reached their predetermined wear limit.

Figure 4 : Haul rope winding around the linings of the bull wheel No. 4

5.9 The on-site measurement of the lining (plastic) of the bull wheel No. 4 after the incident showed that about 45% of the lining (39 out of 87 lining units) already exceeded the wear limit. Uneven worn out of the lining was found.

5.10 Spalling was found in the bearings of the bull wheel No. 4 (please see clause 5.12)

and resulted in the unsmooth rotation of the bull wheel. This unsmooth rotation would lead to intermittent stretching and releasing of the haul rope which caused the uneven worn out of the lining and out-of-roundness of the bull wheel. Subsequently, vibration was induced to the haul rope and thus the bull wheel.

5.11 The measurement record of Ngong Ping 360 was checked and it was noted that the last routine measurement of the lining was conducted on 23 January 2012, i.e. 2 days before the incident. There were 3 out of a total of 12 measurement points marginally exceeding the wear limit. According to the established practice, Ngong Ping 360 had arranged the replacement of the lining but the replacement was yet to be done before the occurrence of the incident on 25 January 2012. The findings suggest that there might be abnormal accelerated wearing of the lining during the 3 days' operation from 23 to 25 January 2012 due to the spalled bearing operation, or the lining measurement conducted on 23 January might not be a thorough and accurate measurement. The findings also reveal that Ngong Ping 360 should enhance their lining replacement arrangement and replace the worn out lining as early as possible upon noticing any excessive wear from the routine measurement.

Bearings of the Bull Wheel No. 4

5.12 Examination of the bearings of bull wheel No. 4 revealed that :

(i) The spalling only occurred in the upper bearing ;

(ii) For the inner ring of the upper bearing, brown staining from corrosion was found at the bottom raceway at the low loaded side (see Figure 6) while heavy spalling was found at the top raceway at the high loaded side (see Figure 5) ;

(iii) In addition to spalling, heavy denting was found on the upper rollers of the upper bearing, as might be expected with the spalled metal fragments and the denting on the upper race (see Figure 7) ; and

(iv) Corrosion/rust was also observed on the outer ring between the upper and lower rollers (see Figure 8).

Figure 5: Spalling in the top raceway of the inner ring of the upper bearing

Figure 6: Corrosion in the bottom raceway of the inner ring of the upper bearing

Figure 7: Pits and dents on rolling element from the top row of the upper bearing

Figure 8: Corrosion in the outer ring of the upper bearing

5.13 Subsequent to the finding of spalling on the upper bearing of bull wheel No. 4, the bearings of the other 6 bull wheels were examined. From visual examination of these bearings, no spalling was found except there was mild corrosion in the bearings of bull

wheel No. 7 and normal wear and tear was observed in most bearings.

5.14 Regular greasing of the bearings is an essential maintenance procedure, aiming at providing lubrication and preventing corrosion or spalling of the bearings. The procedures and frequency of regular greasing of bearings are stipulated in the operation and maintenance manual. The regular greasing of the bearings for the bull wheels has to be conducted in a monthly interval according to the operation and maintenance manual.

5.15 Noting the abnormal spalling of the upper bearing of the bull wheel No. 4, grease samples were taken from the bearings of all the bull wheels for laboratory tests. The results show that :

(i) The main chemical composition of the used and new grease did not show much difference (i.e. no change in the chemical composition of the grease after use) ;

(ii) Moisture of unreasonably large quantities was present in most of the grease samples tested (ranging from 1,000 to 7,000 ppm) which exceeded the level normally expected. Such a high level of moisture should severely degrade the lubricating effect of the grease ; and

(iii) Abnormal brownish colour was noted at some grease samples which were confirmed under laboratory test being the result of fine iron oxide particles formed by wear of the bearing components trapped at the grease. The presence of such iron oxide particles should further degrade the lubricating effect of the grease.

5.16 As reflected from the result of the laboratory tests, it is considered that the spalling of the bearing was mainly caused by ineffective lubrication, arising from high moisture content in the grease leading to degraded lubricating effectiveness. The iron oxide particles in the grease might further degrade the lubricating effect of the grease and accelerate the spalling of the bearing.

5.17 It was noted during site inspection that the unused grease was stored on the catwalk under highly humid environment in Ngong Ping and Tung Chung, awaiting for use at the ensuing greasing work (regreasing in a monthly interval as described in clause 5.14 above). The unsatisfactory storage environment of the unused grease may be a contributing factor to the high water content in the bearing grease, on top of the normal ingress of moisture into the grease during normal bearing operation. Ngong Ping 360 had not taken sufficient precautions to prevent ingress of water moisture into the unused grease

from the ambient environment.

5.18 The bearing spalling arising from poor grease lubrication should have developed for a period of time and eventually caused vibration in the bull wheel and the uneven worn out of lining as detailed in clause 5.10. The uneven worn out of lining would in turn accelerate the development of the spalling. In view of the importance to ensure reliable operation of the bull wheels, monitoring system is provided in the Ropeway to monitor vibration of the bull wheel bearings. However, vibration analysis of the bull wheel bearings was only carried out by Ngong Ping 360 every four months. The last vibration monitoring data, which were measured and collected on 16 December 2011, were checked and considered by the vibration monitoring team to be in acceptable range, despite the vibration monitoring report had already drawn attention to the rising trend of the peak of the vibration level and abrasion of metal. The bearing spalling had then developed to the stage leading to unacceptable bull wheel vibration in only around one month (16 December 2011 to 25 January 2012). The findings reveal that the current interval of vibration monitoring is not able to ensure early identification of defects on the bearings and their timely replacement.

6. Remedial Actions undertaken by Ngong Ping 360

6.1 Taking into account the above findings, Ngong Ping 360 has taken the following actions recommended by EMSD to prevent the re-occurrence of similar incident:

(i) All the bull wheel bearings should be replaced because they all may be subject to the same unsatisfactory greasing condition, which may lead to potential bearing spalling at a later stage.

(ii) Vibration monitoring system of all the bull wheel bearings should be upgraded to capture the vibration data in an on-going basis, while the collected data should be analysed in a more frequent interval (every 2 weeks) against the pre-warning level.

(iii) Grease analysis should be performed monthly to closely monitor the moisture and metal content of the grease, so as to step up the regreasing interval/frequency according to the analysis result.

(iv) Arrangement shall be made to properly store and handle the grease to be

used in order to prevent possible ingress of moisture into the grease

(v) All bearings of the Ropeway shall be completely checked and regreased before resumption of service, noting that the same grease was used.

(vi) The procedures and equipment for the measurement of all bull wheel linings, including the extent of wear and ovality (roundness) along the lining surface, shall be reinforced and clearly specified, so as to ensure more timely identification of worn-out lining and early remedial actions for replacement of the worn-out lining and/or refining the curvature of lining profile.

Additional Enhancement Measures

6.2 Apart from the above immediate actions undertaken, Ngong Ping 360 has taken the following enhancement measures recommended by EMSD to further improve the reliability of the Ropeway and the overall performance in incident handling and reporting:

(i) To make reference to the recent cable car incidents as well as the advancement in cable car related technology, Ngong Ping 360 shall conduct a comprehensive review of the maintenance regime of the whole cable car system, with an aim to identifying improvement areas in the regime to further eliminate any possible maintenance related issues which may lead to prolonged stoppage.

(ii) The emergency handling procedures of Ngong Ping 360 should be enhanced to ensure quick response in making early stop boarding decision upon the detection of abnormal conditions. Refresher training courses for the ropeway maintenance staff should also be provided to ensure their prompt responses to handle abnormal situation.

(iii) The incident reporting mechanism should be strictly observed by Ngong Ping 360 to ensure timely reporting of incident to EMSD.

7. The Three Service Interruptions of the Ngong Ping 360 in December 2011

7.1 Noting that there is also concern from the public regarding the 3 service interruption incidents of the Ropeway in December 2011, findings and improvement measures taken by the Ngong Ping 360 to prevent re-occurrence of similar incidents are given in Appendix 3 of this report.

7.2 The 3 incidents are not related to the concerned components of the incident on 25 January 2012.

7.3 On top of the improvement measures already taken by Ngong Ping 360 as listed in Appendix 3, the implementation of the remedial actions and enhancement measures recommended in Section 6 above should be able to further enhance the reliability of the concerned components of the 3 incidents in December 2011.

8. Conclusions

8.1 The incident occurred on 25 January 2012 at Ngong Ping 360 was caused by the triggering of the position sensor of return bull wheel No. 4 at the AIAS as a result of the vibration of the bull wheel.

8.2 Two factors contributed to the vibration of bull wheel. One factor was the spalling of the upper bearing of bull wheel No. 4 which was likely caused by ineffective lubrication. The other factor was the vibration of the haul rope between bull wheels No. 3 and No. 4 which was likely caused by uneven wear of lining and out-of-roundness of bull wheel No. 4.

8.3 The spalling of the upper bearing of bull wheel No. 4 was mainly caused by ineffective lubrication, arising from high moisture content in the grease leading to degraded lubricating effectiveness. Ngong Ping 360 has not taken sufficient precautions to preserve the unused grease against the moisture of ambient environment.

8.4 The vibration monitoring arrangement for the bull wheel was not able to provide early warning of the failure of bearings for bull wheel No. 4. The measuring interval currently adopted for vibration monitoring is not adequate to ensure early identification of defects on the bearings and their timely replacement.

8.5 Remedial actions to prevent the recurrence of similar incidents have been identified and conveyed to Ngong Ping 360. Ngong Ping 360 has completed the remedial actions and enhancement measures recommended in Section 6 above to improve the reliability of the Ropeway for the use of the public. In addition, Ngong Ping 360 has arranged the annual survey during the stoppage of the Ropeway in February and March 2012. The annual survey was completed on 21 March 2012. The survey findings have been checked with satisfactory result. In conclusion, the actions taken by Ngong Ping 360 before resumption of service are highlighted below:

(i) All the bull wheel bearings have been replaced and checked in order.

(ii) Vibration monitoring system of all the bull wheel bearings has been upgraded to capture the vibration data on an on-going basis. The collected data will be examined every 2 weeks against the pre-warning level.

(iii) Grease analysis will be performed monthly to closely monitor the moisture and metal content of the grease, the regreasing interval/frequency will be stepped up according to the analysis result.

(iv) Arrangement has been made to properly store and handle the grease to be used in order to prevent possible ingress of moisture into the grease.

(v) All bearings of the Ropeway have been completely checked and regreased.

(vi) The procedures and equipment for the measurement of all bull wheel linings, including the extent of wear and ovality (roundness) along the lining surface, have been reinforced and clearly specified, so as to ensure more timely identification and early remedial actions.

(vii) Ngong Ping 360 has conducted a comprehensive review of the maintenance regime of the whole cable car system and completed the immediate action items recommended by the consultant.

(viii) The emergency handling procedures by Ngong Ping 360 have been enhanced to ensure quick response in making early stop-boarding decision upon the detection of abnormal condition. Refresher training

courses for the ropeway maintenance staff have been provided to ensure their prompt responses to handle abnormal situation.

(ix) Annual survey of the Ropeway has been carried out with satisfactory result.

8.6 Most of the measures are of recurrent nature, requiring the staff of Ngong Ping 360 to discharge them in a professional and diligent manner under close and thorough supervision of its management team. Regular examination by external auditor on the compliance of the remedial actions and enhancement measures are deemed necessary. EMSD will continue to keep close monitoring on the operation and maintenance of the Ropeway to ensure the safe operation of the Ropeway.

Electrical and Mechanical Services Department
3 April 2012

Appendix 1

Sequence of Events
Ngong Ping 360 Ropeway
Incident occurred on 25 January 2012

Determination of the Sequence of Events

As a part of the investigation of the ropeway incident occurred on 25 January 2012, the events in their order of occurrence in time before and after the triggering of the fault position sensor at 2:49 pm were analysed.

2. The following table shows the temporal sequence of events regarding the incident which is determined by gathering the information listed below and examining the consistency between them :

(i) Information obtained from interviewing the witnesses and personnel involved in the incident ;

(ii) Information recorded in the operation and maintenance log books ; and

(iii) Information retrieved from SCADA (supervisory control and data acquisition) of the ropeway system (which provides time-based verification of some of the events, including the arrival time of personnel alighted from cable car at the scene and the detection time of the fault position of bull wheel).

Approx. Time	Description of Event
1:45 pm	Two technicians stationed at the Airport Island Angle Station (AIAS) carried out routine patrol inspection of the station equipment. Abnormal noise was heard near bull wheels No. 3 and No. 4. The technicians continued to check and attempted to locate the source of the noise.

Approx. Time	Description of Event
2:00 pm	The technicians located the source of the noise.
2:12 pm	The technicians reported the situation to the Duty Maintenance Supervisor (who was at Ngong Ping Terminal). The technicians also reported the situation to two Assistant Maintenance Managers passed by the AIAS on a cable car cabin. As no prior arrangement was made in the control room at AIAS, the Assistant Maintenance Managers could not alight from the cabin.
2:18 pm (recorded from SCADA)	One of the two Assistant Maintenance Managers rode on the same cabin and returned to the AIAS. This Assistant Maintenance Manager started to inspect the equipment with the two technicians.
2:30 pm	The other Assistant Maintenance Manager disembarked at Tung Chung Terminal (TCT) and notified the Competent Person by telephone about the situation.
2:35 pm	The Competent Person arrived on the scene. The Duty Maintenance Supervisor arrived a few minutes later. The Competent Person made the following instructions to verify if the noise was emitted from bull wheel No. 4 : (i) check the load cell for the rope tension value of bull wheel No. 4 ; (ii) check the alignment of the bull wheels, haul rope; (iii) spray water to linings of bull wheel no. 4 linings for changes in noise ; (iv) check the condition of bull wheels No. 3 and

Approx. Time	Description of Event
	No. 4.
2:49 pm (recorded from SCADA)	Fault position of bull wheel No. 4 was detected by the system which in turn ceased the ropeway operation. At the same time, the Competent Person made the "stop boarding" instruction to the Duty Controller. The Duty Controller ordered to stop passengers boarding at Tung Chung and Ngong Ping Terminals.
2:54 pm	The Duty Maintenance Supervisor applied lubricating grease to the bearings of bull wheel No. 4 for about 5 minutes.
3:22 pm	Limited ropeway operation was resumed. Line clearance (alighting of passengers) was commenced at a reduced running speed of 1 m/s. Some passengers disembarked at the AIAS and the Nei Lak Shan Angle Station (NLSAS) as instructed.
3:29 pm	The Competent Person instructed to increase the running speed of the ropeway to 1.5 m/s and continue the line clearance.
3:40 pm	The Duty Controller informed EMSD about the stoppage of the ropeway by telephone.
4:00 pm	The Competent Person instructed to further increase the running speed of the ropeway to 2 m/s and continue the line clearance. Passengers disembarked at the NLSAS were transported back to Ngong Ping Terminal by cable cars.
4:53 pm	All the onboard passengers were transported back to the terminals without injuries recorded.

Appendix 2
List of Documents Inspected during the Investigation

1. Drive operator log records retrieved from the ropeway monitoring system (for 8.12.2011, 18.12.2011, 22.12.2011 and 25.1.2012)
2. Operation logbook records on 25.1.2012 (hand written)
3. Fault log records from the ropeway monitoring system (on 25.1.2012)
4. Condition Based Monitoring (CBM) analysis report of bull wheel bearings from May 2008 to Dec 2011
5. Preventive maintenance task list of ropeway equipment
6. Maintenance records of bull wheel bearings at the Airport Island Angle Station (AIAS) (Dec 2010 to Dec 2011)
7. Maintenance records of spacers at the Ngong Ping Terminal (NPT) (Dec 2010 to Dec 2011)
8. Maintenance records of roller bearing hub at the Tung Chung Terminal (TCT) (Dec 2010 to Jan 2012)
9. Maintenance records of bull wheel lining at the NPT (Dec 2010 to Dec 2011)
10. Maintenance records of lining of bull wheel No. 4 (Jan 2012)
11. Maintenance manual of haul rope bull wheel bearing
12. Maintenance manual of drive and return drive bull wheel
13. Maintenance manual of drive bull wheel bearing with coupling
14. Work Instruction for greasing of bull wheel bearings
15. Cable car system operations procedures
16. Standing operations procedures
17. Design calculation on drive equipment from the manufacturer
18. Information of manpower of Ngong Ping 360
19. Roster of maintenance staff of Ngong Ping 360 (from Jan 2011 to Dec 2011)

Appendix 3

Incidents of Ngong Ping 360 occurred in December 2011

Date	Stoppage Duration	Reason(s)	Improvement Measures Taken
8 December 2011	16:35 – 16:51 (16 minutes) Cable car operation was stopped to carry out maintenance and testing. 16:51 – 17:21 (30 minutes) Passenger boarding was stopped. The ropeway still continued to operate until all passengers were alighted. Cable car service resumed on the next day.	Partial wear on the haul rope bull wheel lining in the Ngong Ping Terminal. After examination, deformation of the surface of the lining in contact with the bull wheel was found. The acceptance criteria of lining thickness recommended by the manufacturer appeared not sufficient to prevent failure of the lining, and has affected timely replacement.	The incident suggested that there was room for improvement on the maintenance guidelines for the lining. Ngong Ping 360 has made improvement in the maintenance of the concerned lining and has tightened the acceptance criteria for lining thickness to avoid recurrence of similar incidents.
18 December 2011	14:22 – 15:16 (54 minutes) Passenger boarding was	Fault occurred at a small scale roller bearing of the cabin transportation system in Tung	It could not be ascertained whether the particular bearing was sub-standard or due to its unsatisfactory installation.

Date	Stoppage Duration	Reason(s)	Improvement Measures Taken
	stopped. The ropeway still continued to operate until all passengers were alighted. 15:16- 16:15 (59 minutes) Cable car operation was stopped to carry out maintenance and testing. 16:15 Cable car service resumed to normal.	Chung Terminal. After examination, damage was found on a bearing of the roller. Possible causes could be inherent bearing defects or unsatisfactory installation. The roller bearing was replaced overnight as relatively simple procedures and equipment were involved in the replacement work.	Notwithstanding this, in order to avoid recurrence of similar problems, Ngong Ping 360 has already replaced all the 12 bearings of the same type, and reviewed the maintenance arrangement and shortened the replacement schedule.
22 December 2011	16:40 – 16:53 (13 minutes) Cable car operation was stopped to carry out checking and maintenance. 16:53 - 18:07 (1 hour 14 minutes) Passenger boarding was	Fault occurred at the cabin spacer of the Ngong Ping Terminal. After examination, metal particles were found at the planetary gearbox and lubricant oil level was found low.	It is believed that during the regular inspection of the cabin spacer last conducted on 13 December 2011, Ngong Ping 360 did not notice that the lubricant oil level was relatively low. This incident might be related to the NP360's maintenance procedures. The EMSD instructed Ngong Ping 360 on 23 December 2011 to conduct a comprehensive review of

Date	Stoppage Duration	Reason(s)	Improvement Measures Taken
	stopped. The ropeway still continued to operate until all passengers were alighted. Cable car service resumed on the next day.		the maintenance regime of the cable car installations. Ngong Ping 360 has arranged its maintenance staff to attend revision courses and drawn their attention to the essential points to note when inspecting the cabin spacer.

Investigation Summary Report and Mitigation Measures on the Service Disruption of Ngong Ping 360 on 25 January 2012

1. Introduction

This report presents the investigation findings, root cause analysis and the corresponding improvement actions towards the Ngong Ping 360 (NP360) cable car service disruption on 25 January 2012.

2. Review of Incident on 25 January, 2012

2.1 The NP360 cable car service was suspended on 25 January due to irregular wear on the surface of the inner ring of a bullwheel bearing at Airport Island Angle Station (AIAS), affecting the smooth running of the cable car system and thus triggering a stoppage by the automatic monitoring system. Investigation concluded that the wear did not impact the safety of cable car operations but could result in less comfortable rides.

2.2 The concerned bearing was sent to a laboratory for analysis. In the meantime, NP360 replaced the bearings on all seven bullwheels as a prudent measure to boost the reliability of the cable car operations.

2.3 In addition, NP360 appointed an external consultant to conduct a comprehensive review of its maintenance regime.

2.4 A series of improvement measures recommended in the investigation report as well as by EMSD and the external consultant has been completed to enhance system reliability.

3. The Incident

3.1 At 14:49 hours on 25 Jan 2012, the whole NP360 cable car system was stopped by its self monitoring system due to activation of a fault position alarm from the Return Bull Wheel in the AIAS. The alarm indicated an abnormal vibration of the Return Bull Wheel.

3.2 Competent Person (CP) instructed Duty Controller (DC) to stop boarding of passengers at the terminals in accordance with the procedure. CP decided to clear line at low speed after inspection

on site. The line clear process started at 15:22 hours and completed at 16:53 hours. Some 800 passengers were de-boarded in a safe and orderly manner. There was no injury to persons and no damage to properties resulting from the incident.

4. The Investigation

An investigation has been carried out into the cause of the cable car service disruption and was conducted by NP360 engineers, cable car system manufacturer, the bearing manufacturer of the return bullwheel, and an independent cable car expert consultant.

4.1 Observations and Findings

In the investigation, all the other equipment were found to be normal except two abnormalities including spalling found on the upper bearing elements of Bullwheel No. 4 and uneven wearing of lining installed on the circumference of Bullwheel No. 4.

4.1.1 Spalling found on the Upper Bearing Element of the Bullwheel No. 4

Spalling (debris of material off from the bearing body) were found on the pressure zone of the upper raceway of the inner ring and corrosion found on the floating guide position (shallow groove between the upper and lower raceway of the outer ring) around the circumference.

4.1.2 Wearing on the Bullwheel No. 4 Lining

Uneven wearing was found on the lining at Bullwheel No. 4. This would have led to vibration of the haul rope and rubbing noise between the bullwheel and the haul rope.

5. Root Cause Analysis

The immediate cause of the incident was due to vibration of the haul rope leading to the triggering of the position monitoring device at Bullwheel No. 4 at AIAS.

According to the investigation, the grease sample obtained from the incident bullwheel bearing contained higher than normal water content. The excess water reduced the effectiveness of the lubrication which, over time, led to irregular spalling on the incident bearing. This caused uneven wearing of the bullwheel lining, which in turn led to vibration on

the haul rope and thus triggering a stoppage by the automatic monitoring system.

Hence, the root cause of the incident was due to high water content in the bearing grease which led to the spalling on the concerned bearing elements.

It is believed that the highly humid environment of NP360 and the method that the grease was stored caused the water contamination. The investigation also reconfirmed that the wear on the incident bearing did not impact the safety of cable car operations.

6. Recommendations and improvement measures

A series of improvement measures recommended in the investigation report as well as by EMSD and the external consultant has been completed to enhance system reliability. They include:

- Increasing the frequency of inspections of the grease and its water content to once every 4 weeks
- Storing the grease in an enclosed area with humidity control
- Using a more water-resistant grease
- Providing refresher training for maintenance staff on the repair and maintenance regime, especially the controlling humidity in the grease
- Checked and re-greased all the bearings in the cable car system
- Installing an online vibration monitoring device on all seven bullwheels to better collect and analyse the vibration data via computer to check the wear conditions of bearings. Increasing vibration inspection to once every two weeks
- Engaging an external consultant to conduct a comprehensive review of NP360's maintenance regime and implementing the recommendations
- Enhancing the maintenance standard and its wear measuring method on the bullwheel lining, and making earlier replacement according to its actual wear condition
- Strengthening the notification system with EMSD
- Providing refresher training to ropeway maintenance staff to ensure their prompt response to irregular situations

7. Incident handling and customer service enhancements

Based on lessons learned and the feedback from guests during service disruptions, NP360 has also enhanced its incident handling and customer service measures by introducing a range of improvements. They include:

- Enhancing staff guidelines to stop boarding as early as possible once an irregularity is detected. This would help reduce the number of guests on the cable car system in the event of a service disruption. Increasing incident handling training for staff
- Deploying additional bus services to Ngong Ping to transport guests during service disruptions.
- Installing live broadcast capabilities in cabins so that all guests on board will receive the latest information in the event an incident.
- Enhance manning on hotline during an incident for fast and efficient handling of enquiries from in-cabin guests
- Upgrading in-cabin emergency packs to include blankets and warm pads during cold-weather periods
- Setting up a "Guest Care Point" at Tung Chung and Ngong Ping Terminals during long service disruptions to provide guests in need with rest areas, snacks, drinks and travel information
- Improving Ngong Ping 360's communications with travel agents, tour operators and tour guides by inviting them to subscribe to Ngong Ping 360's RSS (Really Simple Syndication) feeds for the latest information during service disruptions. The RSS feeds service is also available for the public.

8. Annual Survey

To assure the condition and normal functioning of the cable car's system, NP360 brought forward the comprehensive annual survey followed by examinations by an independent ropeway surveyor, qualified by EMSD. The annual survey and examination completed last month were traditionally conducted in June each year. EMSD representatives had witnessed the annual survey and the annual survey report was submitted to EMSD.

9. Conclusion

The root cause of the incident was due to high water content in the bearing grease which led to the spalling on the concerned bearing elements. This accelerated the uneven wearing on the concerned bullwheel lining, which in turn led to vibration on the haul rope and thus triggering a stoppage by the automatic monitoring system. It is believed that the highly humid environment of Ngong Ping 360 and the method that the grease was stored caused the water contamination. The investigation also reconfirmed that the wear on the incident bearing did not impact the safety of cable car operation.

Ngong Ping 360 Limited
5 April 2012