AIRCRAFT ACCIDENT REPORT 1/2014

ACCIDENT INVESTIGATION DIVISION

Civil Aviation Department
The Government of the
Hong Kong Special Administrative Region

Report on the accident to Aerospatiale SA 315B LAMA Registration B-HJV operated by Heliservices (Hong Kong) Limited on the hillside of Kau Lung Hang Lo Wai, Fanling, Hong Kong on 3 January 2011

Hong Kong
January 2014

In accordance with Annex 13 to the ICAO Convention on International Civil Aviation and the Hong Kong Civil Aviation (Investigation of Accidents) Regulations, the sole object of this investigation is the prevention of aircraft accidents. It is not the purpose of this activity to apportion blame or liability.

民航處
CIVIL AVIATION
DEPARTMENT

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The Government of the Hong Kong Special Administrative Region

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28 January 2014

The Honourable C Y Leung, GBM, GBS, JP
The Chief Executive
Hong Kong Special Administrative Region
People's Republic of China

Dear Sir,

In accordance with Regulation 10(6) of the Hong Kong Civil Aviation (Investigation of Accidents) Regulations, I have the honour to submit the report by Miss Clara WONG, Inspector of Accidents, on the circumstances of the accident to an Aerospatiale SA 315B LAMA helicopter, registration B-HJV, on the hillside of Kau Lung Hang Lo Wai, Fanling, Hong Kong on 3 January 2011.

Yours faithfully,

(Norman S M LO)
Director-General of Civil Aviation

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GLOSSARY OF ABBREVIATIONS USED IN THE REPORT

A	Ampere
ADF	Automatic Direction Finder
AN(HK)O	Air Navigation (Hong Kong) Order 1995
AOC	Air Operator’s Certificate
ATC	Air Traffic Control
ATPL(H)	Airline Transport Pilot’s Licence (Helicopters)
ATS	Air Traffic Service
CAD	Civil Aviation Department Hong Kong
CLP	CLP Power Hong Kong Limited
COP	Code of Practice
º	Degree
ºC	Degree Celsius
DSC	Director of Safety and Compliance
EMSD	Electrical and Mechanical Services Department
EOC	Emergency Operations Centre
ERP	Emergency Response Plan
FNL	Fanling
FT	Feet
Gearwin	Gearwin Development Limited
GP	General Practice for Contractors Working in Proximity to Electricity Cables and Overhead Lines (issued by CLP)
Heliservices	Heliservices (Hong Kong) Limited
HKO	Hong Kong Observatory
hrs	Hours
IEEE	Institute of Electrical and Electronics Engineers
JPPC	Jilin Province Power Transmission & Substation Project Company
kg	Kilogram
kt	Knot (Nautical Miles Per Hour)
kV	Kilovolt
METAR	Aerodrome Routine Meteorological Report
MHz	Megahertz
OM	Operations Manual
PolyU	PolyU Technology and Consultancy Company Limited
PPE	Personal Protective Equipment
SOO	Senior Operations Officer

TKR	Ting Kok Road
UCARA	Uncontrolled Airspace Reporting Area
UTC	Coordinated Universal Time
V	Volt
VFR	Visual Flight Rules
VHF	Very High Frequency

<u>Notes</u> :

1. When abbreviations are used in this report, the full term is used in the first instance followed by the abbreviation in brackets.

2. All times in this Report are in Coordinated Universal Time (UTC) with Hong Kong Local Time in parenthesis unless otherwise specified.

3. Throughout this report, the use of the male gender (he/him/his) should be understood to include male and female persons.

ACCIDENT INVESTIGATION DIVISION

CIVIL AVIATION DEPARTMENT
HONG KONG

Aircraft Accident Report 1/2014

Aircraft Operator:	Heliservices (Hong Kong) Limited
Aircraft Type:	Aerospatiale SA 315B LAMA Helicopter
Aircraft Registration:	B-HJV
Place of Accident:	Kau Lung Hang Lo Wai, Fanling, New Territories, Hong Kong Latitude: 22° 29.2’ N Longitude: 114° 09.3’ E
Date and Time:	3 January 2011 at 0556 hrs (1356 local time)

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SYNOPSIS

The accident occurred at approximately 0556 hrs (1356 local time) on 3 January 2011 when the Aerospatiale SA 315B LAMA helicopter was conducting an underslung operation on the hillside of Kau Lung Hang Lo Wai, Fanling, along the “Fanling – Ting Kok Road No. 1 132 Kilovolts (kV) Overhead Line Circuit (“FNL-TKR No. 1 Circuit”)”.

When the helicopter was at the final stage of setting down a load at a drop-off site located downhill of Pole 9 of the FNL-TKR No. 1 Circuit, a flashover occurred between the helicopter longline and a live overhead line of the circuit. The fire generated from the flashover and the burning fragments of the longline scattered over the accident site. Patches of fire on the accident site were later extinguished by the ground workers. Two ground workers suffered burn injuries.

After the accident, the helicopter departed the site without the load and returned to its company operating base at Sek Kong. The lower section of the longline was crisped and fragmented with a large portion of the shrouded electrical cable missing. The remote-controlled hook which was connected to the bottom end of the longline was charred. Several items of the aircraft equipment on board the helicopter were found to have been damaged.

One ground worker sustained serious injury to the extent of second degree burns. The other worker suffered minor injuries.

The Chief Inspector of Accidents subsequently ordered an Inspector’s Investigation into the circumstances and causes of the accident in accordance with the Hong Kong Civil Aviation (Investigation of Accidents) Regulations (Laws of Hong Kong, Chapter 448B). The sole objective of the investigation is the prevention of aircraft accidents. It is not the purpose of this activity to apportion blame or liability.

The results of this investigation have revealed that as the helicopter flew and hovered close to the overhead lines, the longline had come close enough to a live overhead line and an earthed object to cause a fault current to flow from the overhead line to the earthed object, triggering a flashover. The flashover lasted for a number of milli-seconds and resulted in a fire and a loud bang, causing damage and injuries.

One safety recommendation has been made which supersedes an earlier recommendation issued during the course of the investigation.

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1 FACTUAL INFORMATION

1.1 History of Flight

1.1.1 On 3 January 2011, an Aerospatiale SA 315B LAMA helicopter, Registration B-HJV, was deployed by Heliservices (Hong Kong) Limited ("Heliservices") to carry out an underslung operation near Kau Lung Hang Lo Wai, Fanling. The operation involved the transport of 57 netted loads of sand, water and cement from the designated staging area to a total of 10 work zones situated along the FNL-TKR No. 1 Circuit of CLP Power Hong Kong Limited ("CLP"). These building materials were to be used by Jilin Province Power Transmission & Substation Project Company ("JPPC") and its subcontractor, Gearwin Development Limited ("Gearwin"), to carry out line pole foundation grouting work on the FNL-TKR No. 1 Circuit.

1.1.2 The location map and planned operational sequence for the day are given at Figures 1 and 2 respectively.

1.1.3 At around 0510 hrs (1310 local time), the helicopter commenced the underslung operation. It took off from its company operating base at Sek Kong and flew to Kau Lung Hang Lo Wai under Visual Flight Rules ("VFR").

1.1.4 The move of the first 18 underslung loads from the staging area to Zone 1 and Zone 2 was uneventful. Having completed the first two zones, the Pilot then proceeded to move the next load (i.e. the 19th load of the day) to Zone 3.

1.1.5 The delivery of the first load to Zone 3 was uneventful. The accident occurred at approximately 0556 hrs (1356 local time) when the helicopter was setting down the second load (i.e. the 20th load of the day) onto the drop-off site in Zone 3 ("the accident site"). A flashover occurred between the helicopter longline and a live overhead line located adjacent to the accident site. The fire generated from the flashover and the burning fragments of the longline scattered over the site. Patches of fire on the site were later extinguished by the ground workers. Two ground workers suffered burn injuries.

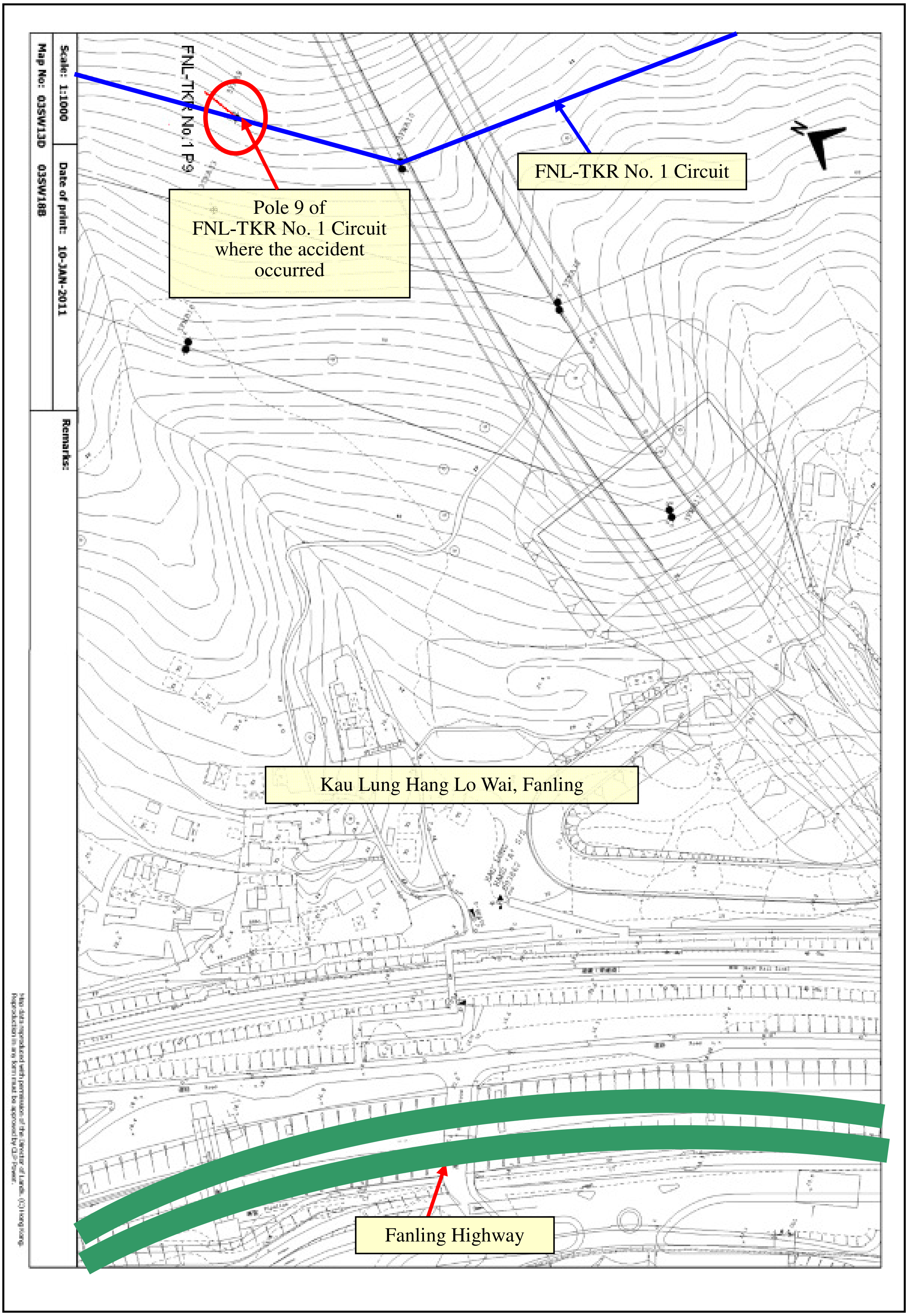


Figure 1 : Location map of the FNL-TKR No. 1 Circuit

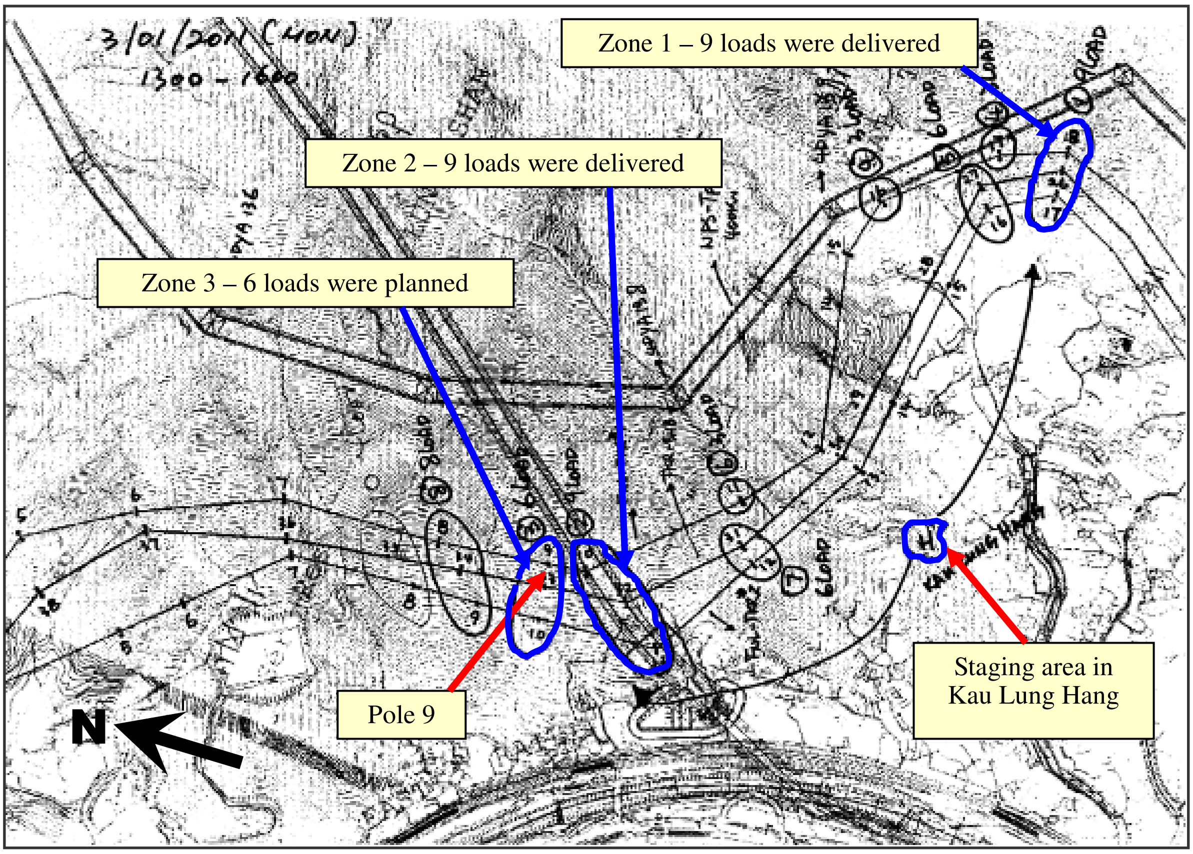


Figure 2 : Map showing the planned operation and loading sequence for the day

1.1.6 In Zone 3, the drop-off site was selected by the Gearwin ground workers on the morning of 3 January 2011. It was located on a steep slope, downhill of Pole 9 of the FNL-TKR No. 1 Circuit (See Photos 1 and 2). It was a clearing of approximately 6 by 8 metres in dimension, surrounded by tall trees and vegetation.

1.1.7 The distance between the staging area and the accident site was about 500 metres. The two locations were out of visual line of sight due to the presence of a low ridge in between.

1.1.8 The accident site was inaccessible by road vehicles.

1.1.9 At Pole 9, there were three live overhead lines located on the two sides of the line pole, namely Phase L1, Phase L2 and Phase L3. Phase L2 was located at the side on which the underslung operation was conducted. The load drop-off point was at a horizontal distance of approximately 3.9 metres downhill from Phase L2 (See Photos 3 and 4).

Photo 1 : An aerial view of the location of the accident site

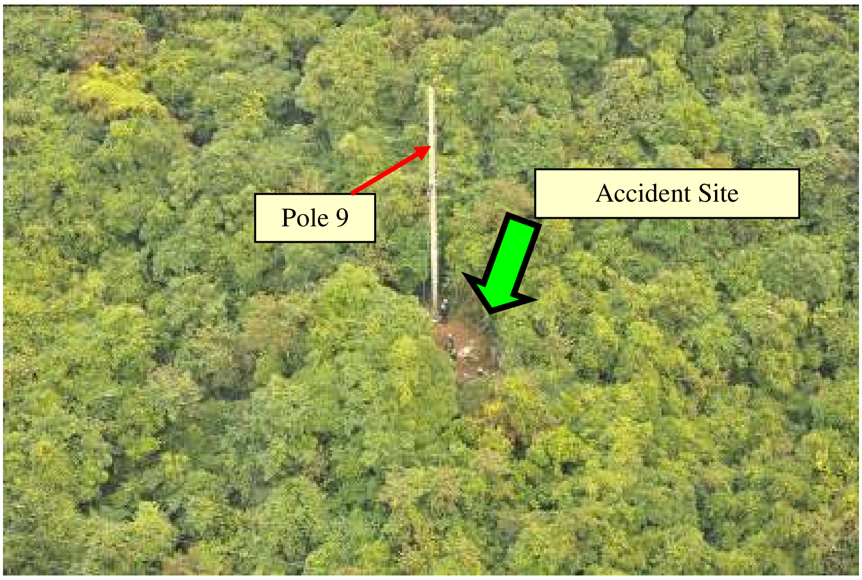


Photo 2 : A closer aerial view of the accident site

(*Note : Photo 2 was taken 2 days after the accident when some tree(s) surrounding the accident site had been cut back.*)

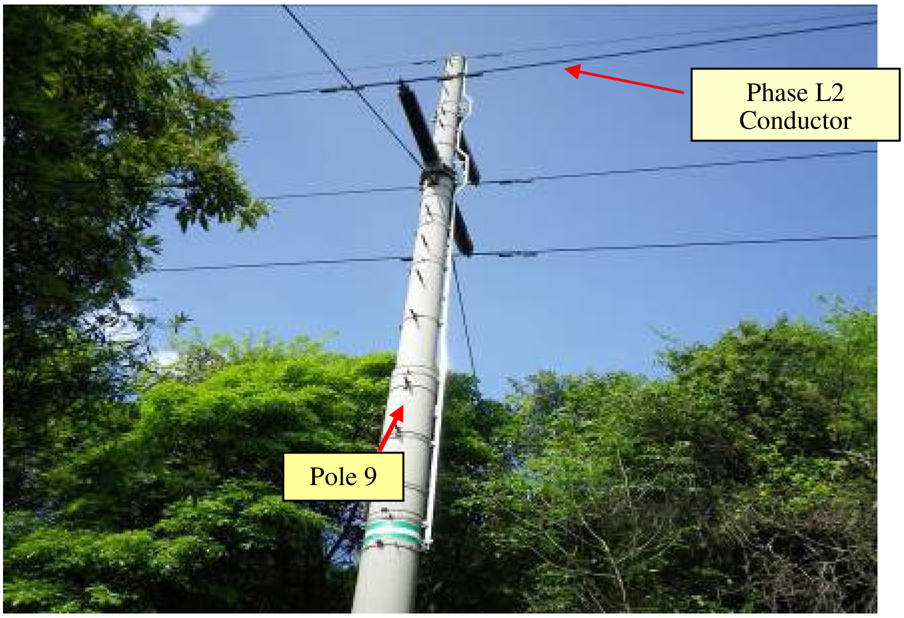


Photo 3 : Pole 9 of the FNL-TKR No. 1 Circuit

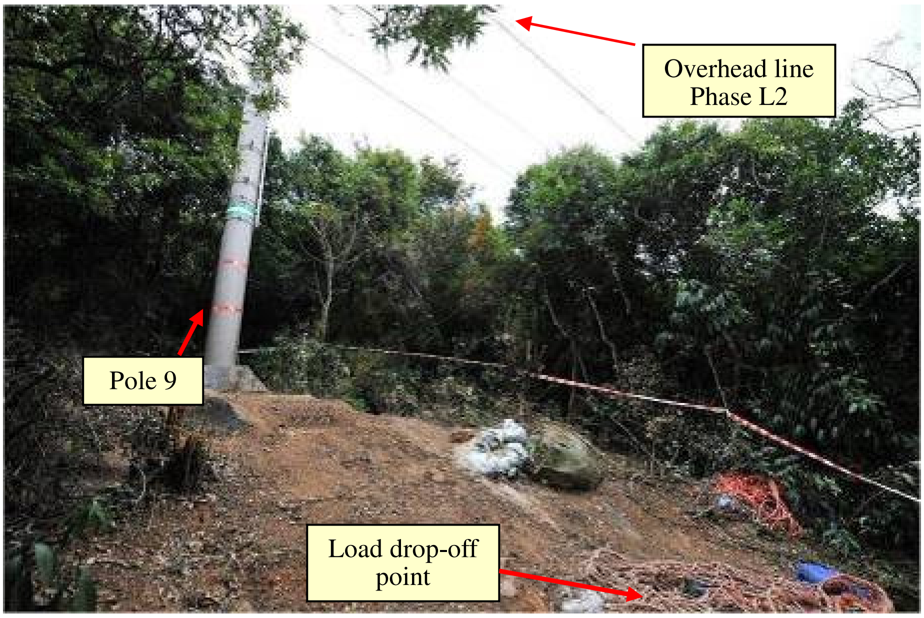


Photo 4 : The relative location of Pole 9 and the accident site

1.2 Injuries to Persons

1.2.1 The accident flight was operated by the Pilot of the helicopter with no other flight crew members on board. Subsequent medical tests confirmed that the Pilot did not suffer any injury as a result of the accident.

1.2.2 Two ground workers of Gearwin at the accident site were injured. One ground worker sustained serious injury to the extent of second degree burns. The other worker suffered minor injuries.

1.2.3 A table summarizing the number of injuries is as follows :

Injuries	Pilot	Total Injuries in helicopter	Others
Fatal	-	-	-
Serious	-	-	1
Minor	-	-	1
Total	0	0	2

Table 1 : Injuries to Persons

1.3 Damage to Aircraft (including the Underslung Assembly)

After the accident, the helicopter underwent a series of comprehensive tests and inspections. There was no evidence of damage or arcing on the fuselage, rotor blades, engine, landing gear and flight control systems. However, several items of the aircraft equipment on board the helicopter and the underslung assembly were found to have been damaged.

1.3.1 Aircraft equipment

The damaged aircraft equipment included the Automatic Direction Finder ("ADF") navigation equipment, transponder, aircraft radio equipment, and the circuit breaker and mission toggle switch of the remote-controlled hook located inside the cockpit. More details are given in Table 2 below :

Damaged Components	Description on the Damage
ADF Navigation System	The ADF navigation system was found blanked. There was no evidence of a burn mark on the component.
Transponder	The transponder component was found blanked. There was no evidence of a burn mark on the component.
Aircraft Radio	The audio amplifier / selector panel was damaged. The internal fuse of the panel was found in open circuit.
Circuit breaker and Mission Toggle Switch of the Remote-Controlled Hook	The circuit breaker and mission toggle switch of the remote-controlled hook were unserviceable after the accident.

Table 2 : Damage to Aircraft Equipment

1.3.2 Underslung Assembly

Both the longline and remote-controlled hook of the underslung assembly were found to have been damaged after the accident (See Photo 5).

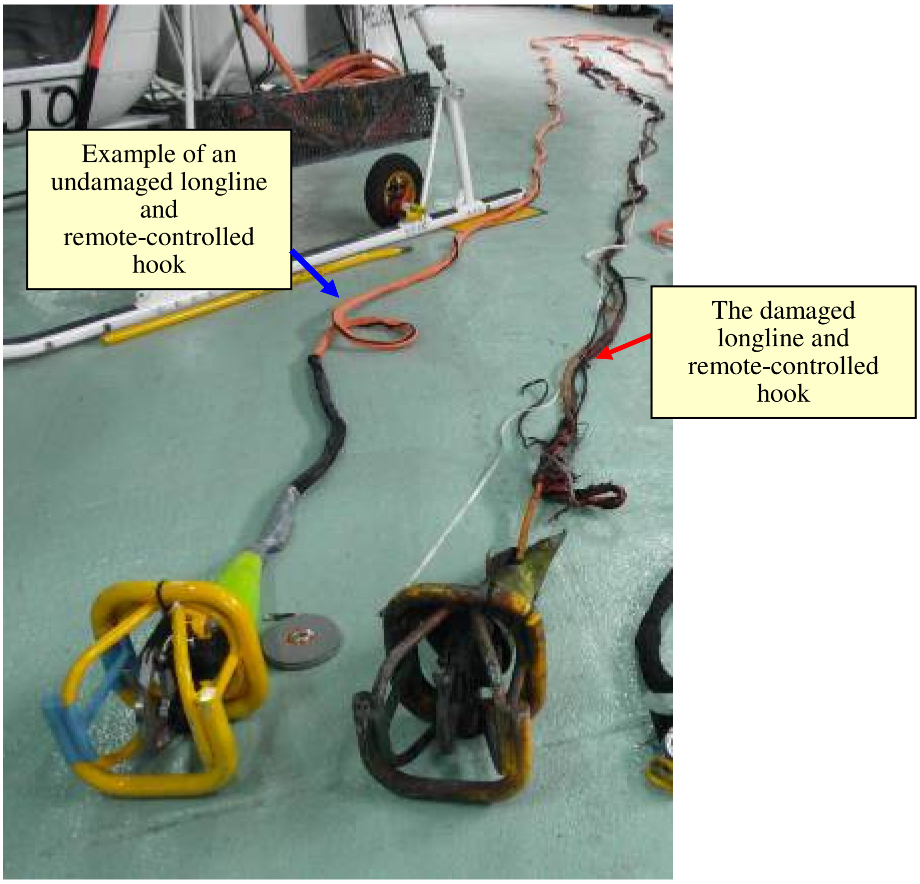


Photo 5 : The longline and remote-controlled hook

1.3.2.1 The Longline

1.3.2.1.1 The lower 11 metres of the 30.5 metres (100-foot) longline's protective nylon jacket was found to have been crisped and fragmented with a large portion of the shrouded electrical cable missing. The yellow rubber sleeve above the remote-controlled hook was also found to have been badly burnt. The length of this damaged section of the longline was consistent with the height of the overhead lines at Pole 9 of the FNL-TKR No. 1 Circuit.

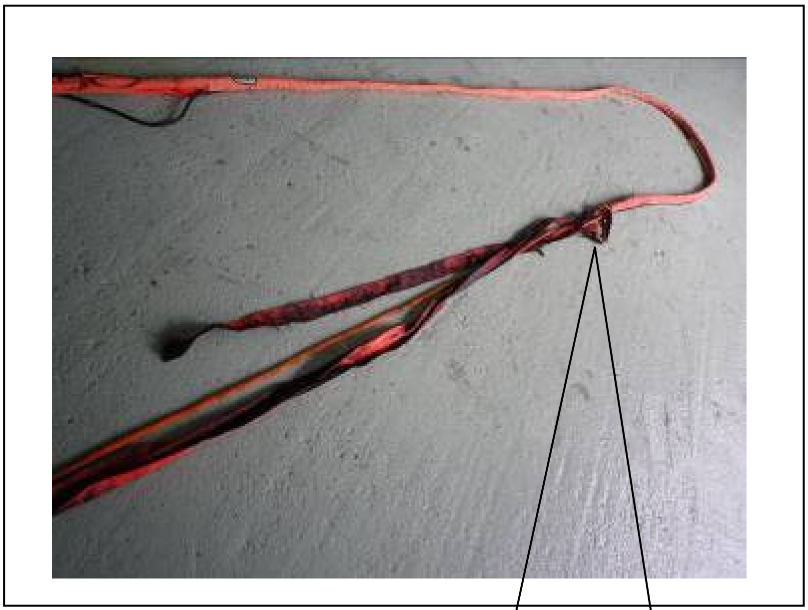
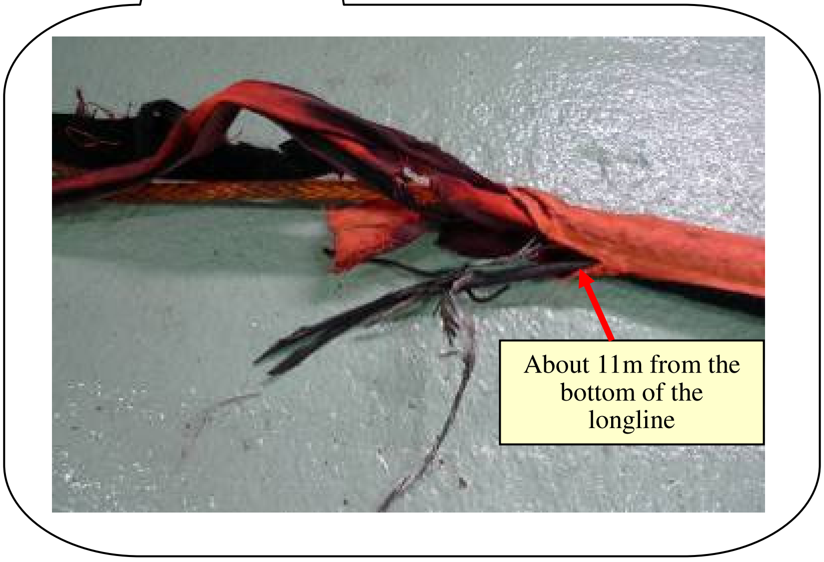


Photo 6 : The damaged longline



About 11m from the bottom of the longline

Photo 7 : A closer view of the portion of the damaged longline, about 11 metres from the bottom end

1.3.2.1.2 Remains of the protective nylon jacket were found to have been scattered over the accident site with some hanging on the nearby tree branches and the Stay Wire which was used to provide mechanical support and anchorage to Pole 9.

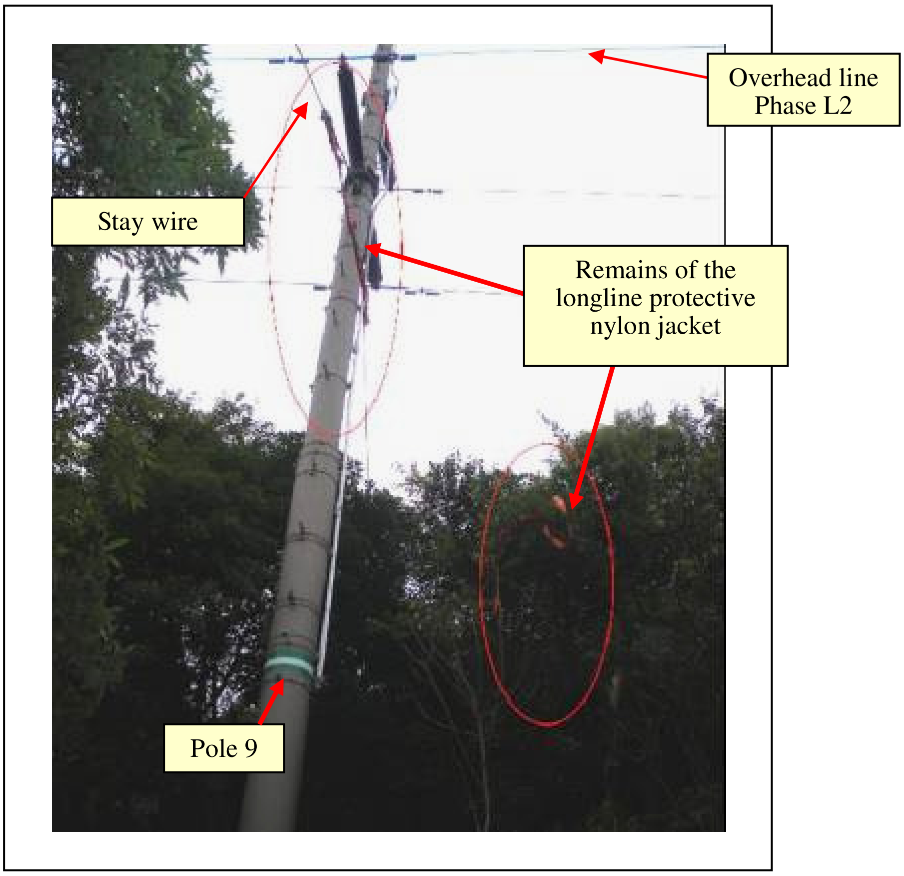


Photo 8 : Remains of the longline's protective nylon jacket found on the Stay Wire and nearby tree branches

1.3.2.1.3 The 3-pin electrical plug which connected the longline's low voltage cable to the helicopter electrical circuit was found to have been damaged.

Photo 9 : The damaged electrical plug (left) and example of an undamaged electrical plug (right)

1.3.2.1.4 The upper 20 metres portion of the longline was found to have remained mostly intact and undamaged, except for some burn marks found along the protective nylon jacket and minor damage was found at a few locations of the low voltage electrical cable.

Photo 10 : A close view of the upper portion of the longline where burn marks and slight damage were found

1.3.2.2 Remote-controlled Hook

1.3.2.2.1 The remote-controlled hook which was connected to the bottom end of the longline was charred, showing clear burn marks and signs of flashover. The release mechanism was damaged with an unserviceable solenoid.

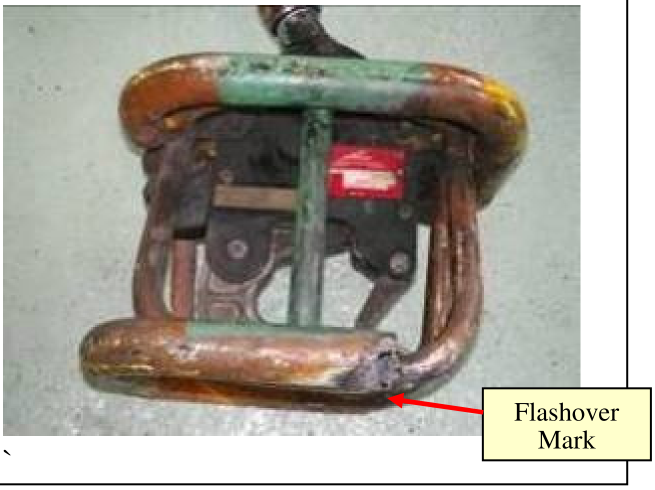


Photo 11 : The charred remote-controlled hook

1.3.2.2.2 The bearing which connected the longline to the remote-controlled hook, allowing turning movements of the two parts, seized up.

Photo 12 : The seized bearing

1.4 Other Damage

1.4.1 Flashover marks on the Overhead Electrical Line System

1.4.1.1 Some white flashover marks and patches were found on the overhead Phase L2 conductor at locations approximately 2 to 4 metres from Pole 9 towards Pole 10. This indicated that flashover had occurred at or close to this area. The event log of CLP (See Section 1.16.2 and Appendix A) which showed substantial disturbances in the voltage and current waveforms of Phase L2 also confirmed that a short circuit had occurred in Phase L2 of the FNL-TKR No. 1 Circuit.

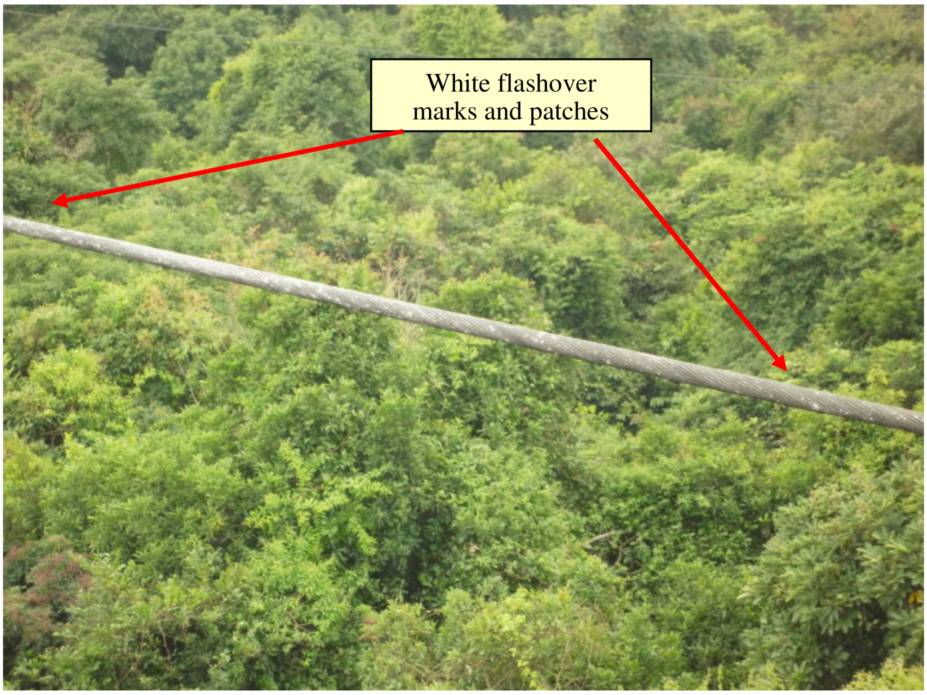


Photo 13 : White flashover marks and patches found on the overhead Phase L2 conductor

1.4.1.2 Burn marks were also found at various earth connection points on the pole, including at the top of Pole 9 where it connected the aerial return wire and at the bottom of the pole where it connected to ground.

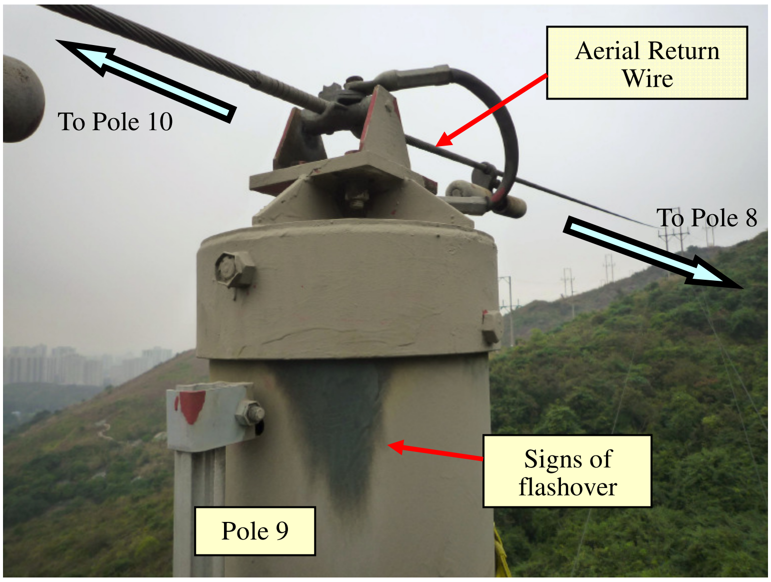


Photo 14 : Burn mark at the top of Pole 9

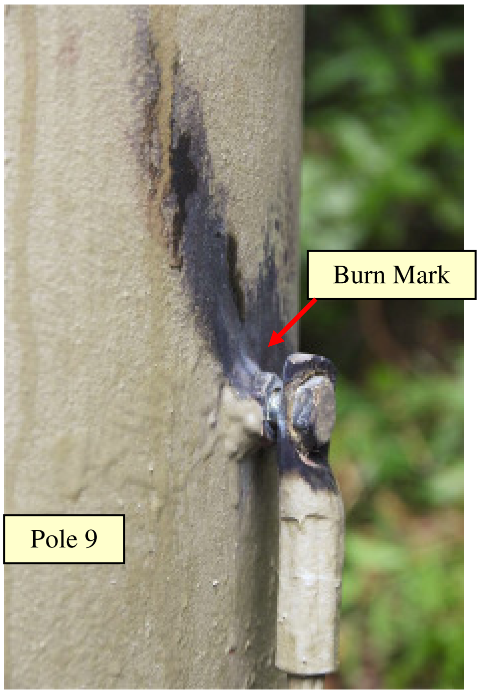


Photo 15 : Burn mark at the earth connection point to ground at the bottom of Pole 9

1.4.2 **Other objects**

1.4.2.1 Some of the tree branches surrounding the accident site were also found to have been burnt.

Photo 16 : Burnt tree branches surrounding the accident site

1.4.2.2 The clothing and Personal Protective Equipment ("PPE") of the injured ground workers was burnt and damaged.

Photo 17 : Burnt PPE of the workers

1.4.2.3 Unlike the underslung assembly, the cargo net and the “8-shaped” hook, which connected the cargo net to the underslung assembly, were left at the accident site alongside the cargo load. They were found mostly intact with no burn marks or mechanical damage.

Photo 18 : The “8-shaped” hook

1.5 Personnel Information

1.5.1 The Pilot

1.5.1.1 The Pilot was the only person on board the accident flight. He was properly licensed for the underslung operation on 3 January 2011. Some basic details of the Pilot's licence, qualifications and experience are as follows :

Licence	Airline Transport Pilot's Licence (Helicopters) [ATPL(H)] issued by the Civil Aviation Department Hong Kong (CAD) Renewed on 15 October 2010 Valid until 30 October 2020
Aircraft Ratings	Aerospatiale AS 350BA, SA 315B LAMA and AS 355N helicopters; McDonnell Douglas MD 500 and MD 520N helicopters
Last Certificate of Test on Aerospatiale SA 315B LAMA	18 August 2010 – valid
Medical Certificate	Class One Standards Renewed on 24 August 2010 Validity : (i) valid until 28 February 2011 for single-crew commercial air transport operations carrying passenger (ii) valid until 31 August 2011 for commercial air transport operations other than (i) above.
Flying Experience	8,766 hrs (of which 4,023.8 hrs were on type) Last 28 days – 71.3 hours

Table 3 : Pilot's Details

1.5.1.2 With reference to the Heliservices Operations Manual (“OM”), the Pilot was also properly qualified by the company to conduct underslung tasks in the transmission line environment.

1.5.1.3 According to the Pilot, he had carried out similar tasks on previous occasions near the same set of high voltage overhead electricity lines. The underslung task on 3 January 2011 was therefore not an operation he was unfamiliar with.

1.5.1.4 According to the Pilot’s descriptions, the underslung operation on 3 January 2011 was his second flight of the day. He reported for work at 2245 hrs on 2 January 2011 (0645 local time, 3 January 2011) and took off for his first flight which constituted a proficiency check on another company pilot at 2330 hrs on 2 January 2011 (0730 local time, 3 January 2011). The proficiency check flight lasted for approximately 90 minutes and he returned to the company operating base at Sek Kong at around 0100 hrs (0900 local time). With his next flight scheduled at 0500 hrs (1300 local time), he had approximately 4 hours of break and flight preparation time between his first and second flight. His pre-flight preparations included a weather check, a study of the job description and routes to be flown.

1.5.2 The Loadmaster

1.5.2.1 The Loadmaster was the ground representative of Heliservices assigned to attend at the staging area on 3 January 2011. His main responsibility was to oversee the loading and unloading operation at the staging area, and to act as an intermediary between the Pilot, Gearwin Foreman and the workers. He had worked for Heliservices for 20 years.

1.5.2.2 On 3 January 2011, the Loadmaster arrived at the staging area before 0500 hrs (1300 local time). After confirming with the Gearwin Foreman that all of the ground workers were ready, he notified the company Operations Unit by phone to launch the helicopter. The helicopter took off from its base at Sek Kong at approximately 0510 hrs (1310 local time) and flew to Kau Lung Hang Lo Wai to commence the underslung operation.

1.5.2.3 Apart from the mobile phone, the Loadmaster also carried a mobile radio which he could use to communicate with the Pilot in flight on company VHF frequency 134.1 MHz. At the staging area, he communicated with the Gearwin Foreman and other ground workers through direct speech or hand signals. The Loadmaster did not have the telephone contact details of the Foreman or the workers at the drop-off site.

1.5.2.4 According to the Loadmaster, he was not required by the company to make any visit or inspect the drop-off sites prior to the operation. He also mentioned that it would not be possible for him to inspect every ground safety training ID card of the ground workers at each of the drop-off sites. Heliservices OM only required him to conduct random on-site inspection of the cards.

1.5.3 Gearwin Foreman at the Staging Area

1.5.3.1 The Gearwin Foreman working at the staging area was not known to the Loadmaster but was introduced to him by another foreman of Gearwin on the morning of 3 January 2011 at the staging area. He was the representative of Gearwin who supervised the team of ground workers and the ground operation for the day. His main responsibility was to oversee the loading and unloading sequence and operations, and to coordinate with the Loadmaster at the staging area and with the ground workers at the different drop-off sites.

1.5.4 Gearwin Ground Workers at the accident site

1.5.4.1 At the time of the accident, Gearwin had deployed four ground workers to support the helicopter underslung operation on ground at Zone 3. According to the ground workers, their respective work responsibilities and relative locations were as follows :

Worker 1	Worker 1 was standing about 1 to 2 metres uphill of the load drop-off point, responsible for giving hand signals to the Pilot. He attended Heliservices ground safety training in August 2010. He suffered serious burn injuries as a result of the accident.
Worker 2	Worker 2 was standing underneath the Stay Wire at the site boundary, some distance away from the load drop-off point. He was responsible for holding up a coloured board, to indicate the exact location of the drop-off site to the Pilot. He attended Heliservices ground safety training in August 2010. According to Worker 2's description, he had turned around to put away the coloured board when the accident took place. He therefore did not witness the accident. He did not suffer any injury from the accident.
Worker 3	Worker 3 was standing about 1 metre uphill of Worker 1. He was responsible for assisting in relocating the load contents after the load was delivered. He suffered minor injuries as a result of the accident.
Worker 4	Worker 4 was standing near the trees at the site boundary when the accident occurred. He was responsible for unhooking the cargo load and re-hooking the empty net from the previous load onto the secondary hook. He did not suffer any injury from the accident.

Table 4 : Details of Gearwin Ground Workers at the Accident Site

1.5.4.2 A diagram depicting the relative positions of the workers at the time of accident is given at Figure 3.

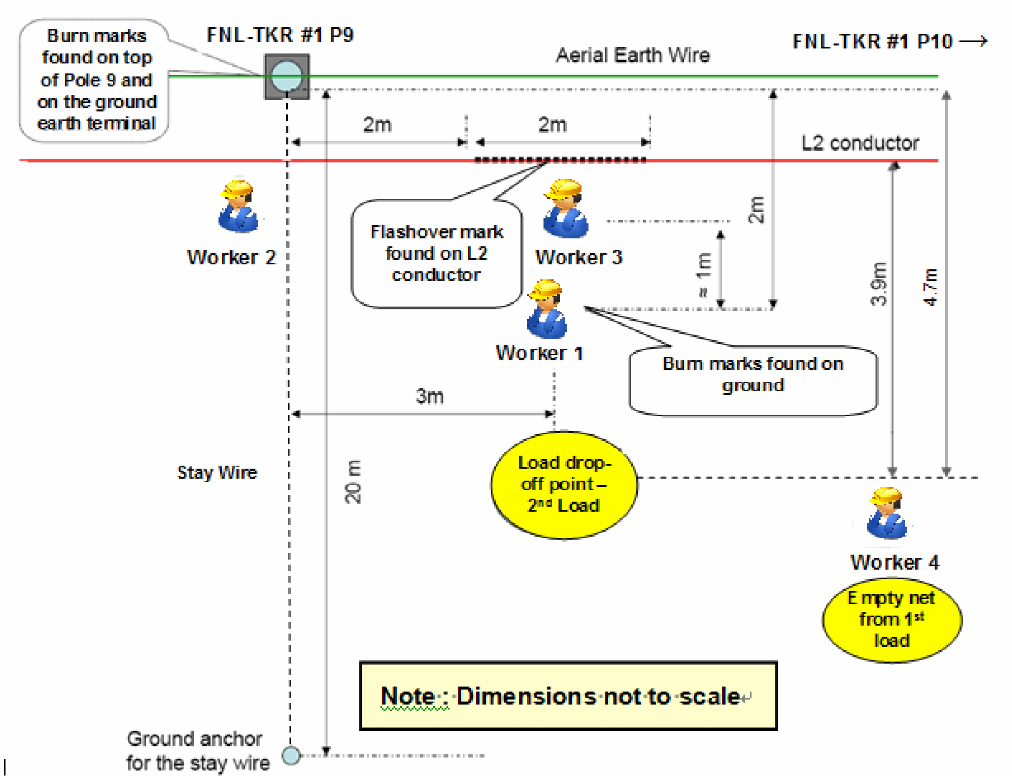


Figure 3 : Schematic diagram showing the relative positions of the workers at the site at the time of the accident

1.5.4.3 Several months prior to the accident, two of the four ground workers (Workers 1 and 2) had attended a ground safety training course with Heliservices. The content of training included the safety precautions to be taken in association with operations with a helicopter, hooking, unhooking and rigging of loads, the use of hand signals, and other appropriate procedures. After completion of the training, the two ground workers were issued a ground safety training ID card which carried a validity of 12 months. According to Heliservices OM, only those personnel in possession of a valid training ID card were permitted to hook and unhook loads from a helicopter during an underslung operation.

1.5.4.4 Neither Worker 3 nor Worker 4 had received or refreshed their ground safety training with Heliservices in the 12 months preceding the accident.

1.6 Aircraft Information

1.6.1 Aircraft Particulars

General	
Manufacturer	Aerospatiale
Model	SA 315B LAMA
Serial Number	2316 / 33
Year of Manufacture	Manufactured in 1972 as an Alouette 318C; Aircraft was re-built into a SA 315B LAMA in 1990
Nationality / Registration	B-HJV
Certificate of Registration	Certificate number 524, issued on 1 July 2009
Name of Owner	CLP Power Hong Kong Limited
Name of Operator	Heliservices (Hong Kong) Limited
Certificate of Airworthiness	Certificate number 382-8, renewed on 3 August 2010, valid until 10 August 2011
Engine	One Turboméca ARTOUSTE III B turboshaft engine
Maximum Certified Weights	
Take-off and landing (with non- releasable loads)	1,950 kg
Take-off and landing (with releasable loads)	2,300 kg
Underslung load	1,134 kg
Total Airframe Hours	
Total airframe hours	11,128.3 hrs

Table 5 : Aircraft Technical Data

1.6.2 **Airworthiness and Maintenance of Aircraft**

1.6.2.1 The helicopter was first issued a Certificate of Airworthiness in the Transport (Passenger) Category in Hong Kong by the CAD on 9 April 2002. At the time of the accident, the aircraft had a valid Certificate of Airworthiness with expiry on 10 August 2011. It was also issued with a Certificate of Maintenance Review dated 14 July 2010.

1.6.2.2 Aircraft technical records indicated that the helicopter had been maintained in accordance with the CAD approved maintenance schedule and that there had not been any significant airworthiness issues. The most recent scheduled maintenance check was a 50-hour Inspection carried out on 28 December 2010. At the time of the inspection, the airframe had accumulated 11,112.1 flight hours since new.

1.6.2.3 A review of the Aircraft Log Book indicated that the helicopter had no outstanding defects prior to the accident flight. The helicopter was fully serviceable in all respects prior to the accident.

1.6.2.4 The helicopter was grounded after it returned to its Sek Kong base after the accident. A series of comprehensive tests and inspections were carried out with all unserviceable components identified and replaced before it was released for service.

1.6.3 **Performance and Centre of Gravity**

1.6.3.1 Evidence has shown that the helicopter was operating within its longitudinal and lateral centre of gravity limits during all phases of the flight. The take-off weight of the helicopter from its base at Sek Kong was calculated to be 1,470.6 kg. Prior to the accident, the weight of the helicopter (with the underslung load) was approximately 2,200 kg (100 kg below the maximum allowable with releasable load). The weight of the underslung load was estimated to be less than 840 kg, well below the maximum authorized underslung load weight of 1,134 kg.

1.6.4 Carriage of External Underslung Loads

1.6.4.1 General

1.6.4.1.1 Aerospatiale SA 315B LAMA is a single-engined helicopter developed, manufactured and marketed as suitable for the conduct of aerial operations. Equipped with a cargo hook underneath the helicopter (also called the "primary hook"), external underslung loads may be carried by the helicopter.

1.6.4.1.2 The helicopter had an onboard load indicator in the cockpit to verify the weight of the load.

1.6.4.1.3 The helicopter was certificated for single pilot operations from the right hand seat.

1.6.4.2 Underslung Assembly used on the Accident Flight

1.6.4.2.1 For the subject underslung operation on 3 January 2011, the underslung assembly used on the helicopter was connected to the helicopter primary hook at its Sek Kong base before commencement of the underslung operation. It included a 30.5-metre (100-foot) longline and a remote-controlled hook (also called the "secondary hook"). The longline comprised a high modulus Polyethylene rope and a 300 Volt (V) low voltage electrical cable, shrouded in a protective nylon fabric jacket (See Photo 19). Fitted to the bottom end of the longline was the secondary hook. Loads could be unhooked manually from the secondary hook by the ground crew, or electrically released by the pilot through the activation of a push-button in the cockpit with the mission toggle switch armed.

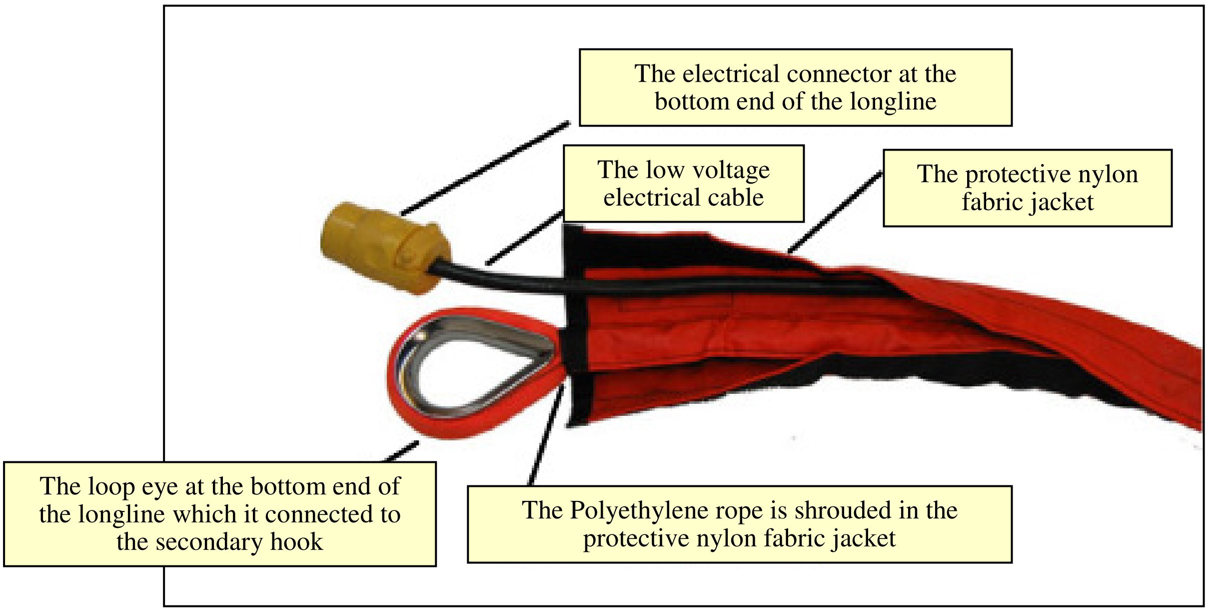


Photo 19 : Basic structure of the longline

1.6.4.2.2 The underslung assembly did not form part of the helicopter airframe. It was connected to the helicopter electrical system through an electrical connector fitted to the helicopter.

1.6.4.2.3 Instructions in the helicopter Flight Manual Supplements stipulated that all items of the underslung assembly shall be inspected for condition and security before use and that they shall be examined and overhauled as necessary in accordance with the manufacturer's requirements.

1.6.4.2.4 In addition, all lifting gear shall be examined and load tested on a six-monthly basis under the Factories and Industrial Undertakings (Lifting Appliances and Lifting Gear) Regulations (Laws of Hong Kong, Chapter 59J, Regulation 18(1)(e)).

1.6.4.2.5 Results of the investigation have revealed that the general condition of the subject longline and remote-controlled hook had been checked by the Pilot prior to the accident flight on the day. Appropriate examination and certification had been conducted and obtained from the relevant parties and authorities.

1.7 Meteorological Information

1.7.1 Weather Forecast and Observations

1.7.1.1 Weather Information issued by the Hong Kong Observatory (“HKO”).

The HKO issues Aerodrome Routine Meteorological Report (“METAR”) at half-hour intervals and Local Aviation Forecasts for 100-kilometre radius around Hong Kong three times a day. The METARs issued between 0500 hrs (1300 local time) and 0600 hrs (1400 local time), and the Local Aviation Forecast at 0130 hrs (0930 local time) by HKO were as follows:

(i) METARs at the Hong Kong International Airport observed and issued between 0500 hrs (1300 local time) and 0600 hrs (1400 local time):

0500 hrs (1300 local time):
“VHHH 030500Z 04009KT 360V060 9999 FEW018 SCT024 11/05 Q1020 NOSIG=”

0530 hrs (1330 local time):
“VHHH 030530Z 36011KT 340V040 9000 -RA FEW018 SCT022 11/06 Q1020 NOSIG=”

0600 hrs (1400 local time):
“VHHH 030600Z 36012KT 5000 -RA FEW018 SCT022 11/07 Q1020 NOSIG=”

(ii) Extracts of the Local Aviation Forecast issued at 0130 hrs (0930 local time) for the period from 0200 hrs (1000 local time) to 1200 hrs (2000 local time):

Surface wind: *030°/10-15 knots*
Offshore wind: *050° / 15-20 knots, occasional 25 knots*
Temperature: *12-16 °C*
Weather: *Cloudy with a few light rain patches. Localized mist.*
Cloud (AMSL): *FEW 2000 FT SCT 3000 FT BKN 8000 FT*
Visibility: *7 kilometres. TEMPO 4000 metres in mist/rain.*
Further Outlook: *Moderate to fresh north to northeasterly winds. Mainly cloudy.*

1.7.1.2 After the accident, the HKO provided the CAD with additional information on the weather and wind conditions over the northeastern part of the New Territories :

"*At 0513 hrs (1313 local time), the weather over the northeastern part of the New Territories was generally cloudy with light to moderate wind coming from a northerly direction. The lowest cloud base was at around 2000 feet. Visibility was at least 5 kilometres.*"

1.7.1.3 The wind data recorded by HKO's anemometer at Ta Kwu Ling, which was located approximately 6.5 kilometres northeast of the accident site at Kau Lung Hang Lo Wai, Fanling, on 3 January 2011 was tabulated as follows :

Time (UTC)	**Time (Local Time)**	**10-min mean wind speed (knot)**	**10-min mean wind direction (degrees)**	**10-min gust (knot)**
0500	1300	5	352	10
0505	1305	5	350	11
0510	1310	6	351	11
0515	1315	7	352	11
0520	1320	7	353	12
0525	1325	7	357	15
0530	1330	7	358	15
0535	1335	6	354	11
0540	1340	6	351	11
0545	1345	5	351	10
0550	1350	5	354	11
0555	1355	6	356	11
0600	1400	7	359	15
0605	1405	6	002	15

Table 6 : Wind data recorded at Ta Kwu Ling on 3 January 2011

1.7.2 Meteorological Information Available to Heliservices

Heliservices was a subscriber of the Aviation Meteorological Information Dissemination System of the HKO. This system displayed, inter alia, METAR, Local Routine Report, Local Aviation Forecast and Winds around Hong Kong. In addition, Heliservices had access to the HKO internet website which provides information on aviation weather observations and forecasts.

1.7.3 Meteorological Information Obtained by the Pilot

According to the Pilot, he checked the weather reports before the flight. He noted that the weather was overcast with a northerly wind of 5 to 10 knots.

Enroute to Kau Lung Hang Lo Wai, Fanling, he carried out routine checks and further assessed that the wind was about 5 to 10 knots coming from the northerly or north-westerly direction. His assessment generally aligned with the weather observation and information recorded by the HKO.

1.8 Aids to Navigation

The accident flight was operated in daylight under VFR, during which the helicopter was required to remain clear of cloud and in sight of the surface. Visual contact with the surface was the principal method of navigation.

The accident helicopter was equipped with appropriate navigation equipment for the flight.

1.9 Communications

1.9.1 The accident site was located in one of the seven Uncontrolled Airspace Reporting Areas ("UCARAs") known as "New Town". In accordance with the Hong Kong Aeronautical Information Publication issued by the CAD, UCARAs are classified as a Class G airspace and aircraft operating in these areas are required to maintain two-way radio communication with Air Traffic Control ("ATC") on the designated VHF frequency 121.0 MHz.

1.9.2 At 0513 hrs (1313 local time), the Pilot advised ATC that the helicopter had commenced the underslung task in New Town. He also indicated to ATC that he would make the next Operations Normal call at 0600 hrs (1400 local time).

1.9.3 Besides communicating with ATC, the Pilot also maintained two-way communication with the Loadmaster on company VHF frequency 134.1 MHz prior to the accident. After the accident, the Pilot made several attempts to communicate with the Loadmaster using the two aircraft radios on board (i.e. COM 1 and COM 2) and also with ATC on COM 1. However, no radio contact could be established as a result of the damage to the aircraft radio equipment.

1.9.4 ATC initiated several radio calls to the helicopter at around 0600 hours (1400 local time). No response was received. ATC was later informed by Heliservices that the helicopter had returned and landed at its base at approximately 0605 hrs (1405 local time).

1.9.5 At the staging area and the drop-off sites, hand signals were used as the means of communication between the ground workers and the Pilot during loading and unloading operations. A set of standard hand signals was prescribed in the Heliservices OM.

1.10 Aerodrome Information

The accident took place at Kau Lung Hang Lo Wai in Fanling. Aerodrome information is not relevant.

1.11 Flight Recorders

The helicopter was not fitted with any flight recorder and there was no requirement for this class of helicopter to be so fitted.

1.12 Wreckage and Impact Information

Not applicable.

1.13 Medical and Pathological Information

1.13.1 The Pilot

1.13.1.1 After the accident, the Pilot departed the accident site and flew back to the company base at Sek Kong. According to his descriptions, he did not feel very well and was concerned about his physical condition. He therefore decided to fly back to the base at Sek Kong immediately. He also mentioned that he thought about landing in a field near the accident site, however, he later decided against it and returned to base to get to the hospital as quickly as possible.

1.13.1.2 After the Pilot had returned to the Sek Kong base, he was taken to the Prince of Wales Hospital where he undertook some tests and cardiac monitoring. It was later confirmed that he had suffered no injury from the accident. He was discharged from the hospital on the same day of the accident.

1.13.1.3 There was no evidence to suggest that the performance of the Pilot had been affected by fatigue, alcohol, drugs and/or medication at the time of the accident.

1.13.2 The Ground Workers – Worker 1 and Worker 3

1.13.2.1 Worker 1 sustained serious injury to the extent of second degree burns. He was first treated by the emergency rescue crew who attended the scene after the accident, and was then sent to the Prince of Wales Hospital where he received further medical attention. According to his medical reports, he was found to have mixed depth burns involving over 40% of his total body surface area. He was hospitalized for approximately six weeks.

1.13.2.2 Worker 3 suffered minor injuries as a result of the accident. He was sent to the North District Hospital where he received medical treatment. He was discharged the following day.

1.14 Fire

1.14.1 From the witness accounts and other evidence collected, it was revealed that a fire had occurred as a result of the flashover. The fire caused burn damage to the helicopter underslung assembly and the burning fragments of the longline scattered over the accident site. Patches of fire were seen which were later extinguished by the ground workers using sand extracted from the unloaded cargo. The fire also caused burn injuries to the two ground workers who were standing closest to the load drop-off point.

1.15 Survival Aspects

1.15.1 At 0649 hrs (1449 local time) on 3 January 2011, i.e. 53 minutes after the accident, a call was made to the '999' hotline alerting emergency services to the accident. This call was made by a Gearwin representative who arrived at the site after the accident.

1.15.2 On receipt of the alert, two ambulances and fire engines were immediately despatched from the Fanling stations, i.e. the Fanling Ambulance Depot and Fanling Fire Station respectively, to respond to the emergency call. A Government Flying Service helicopter was later also tasked out.

1.15.3 Within 10 minutes from the call, the first ambulance and fire engine arrived at the nearest vehicle staging area on Tai Wo Service Road East at the outskirts of Kau Lung Hang Shan. As the accident site was located on the hillside of Kau Lung Hang Lo Wai which was not accessible by road vehicles, the emergency rescue crew had to proceed uphill on foot. Gearwin representatives who met the emergency rescue crew at Tai Wo

Service Road East guided the crew to the site. The crew arrived at the scene at 0720 hrs (1520 local time).

1.15.4 On arrival, Worker 1 who suffered serious burn injuries was seen lying on his back on the steep slope, assisted by Worker 3 who had also suffered minor injuries. The thick winter clothing and PPE of both workers which included inter alia, a safety helmet, safety shoes and work gloves, were burnt and damaged.

1.15.5 The emergency rescue crew quickly performed first aid treatment on Worker 1. He was then conveyed downhill by the emergency rescue crew without delay, and was taken to the Accident and Emergency Department of the Prince of Wales Hospital by ambulance at 0755 hrs (1555 local time).

1.15.6 Worker 3 who suffered minor injuries was able to proceed downhill unaided. He was later conveyed to the North District Hospital by ambulance at 0759 hrs (1559 local time).

1.16 Test and Research

1.16.1 During the course of investigation, a series of laboratory tests and research were conducted on the longline and various items of the aircraft equipment in order to determine the circumstances and causes of the accident. To assist the team in doing so and to provide the team with independent specialist advice in the field of electrical engineering, the PolyU Technology and Consultancy Company Limited ("PolyU"), a company with an extensive level of expertise and experience in the area of high voltage electricity supply and transmission in Hong Kong, was engaged for the purpose.

1.16.2 Firstly, the event log of CLP on the FNL-TKR No. 1 Circuit and the associated sub-stations before and after the accident was reviewed (See Appendix A). It showed that within a short duration of approximately 168 milli-seconds between 0556 and 0557 hrs (between 1356 and 1357 local time), there were substantial disturbances in the voltage and current waveforms of Phase L2 of the FNL-TKR No. 1 Circuit. This indicated that a short circuit had occurred in Phase L2 of the FNL-TKR No. 1 Circuit. Phases L1 and L3 only showed minor consequential disturbance due to the short circuit in Phase L2, indicating that there was no short circuit in these two phases.

1.16.3 Expert advice from PolyU further indicated that if an external object had come sufficiently close to the Phase L2 conductor and an earthed object, a short circuit may occur, causing a flashover. Other possible causes of short circuit including transient surges of electricity in the CLP's electrical system and lightning strikes were also considered. However, as the event log of CLP showed no transient surges of electricity in the CLP's electrical system before and after the accident, the possibility of an electrical disturbance due to switching or transient actions to cause a local flashover among the overhead lines was ruled out. Furthermore, with no record of lightning strikes at the time of the accident, no sign of unduly high voltage disturbance in the event log of CLP, and coupled with the fact that the extent of damage to the overhead lines after the accident (mainly burn marks) was inconsistent with the extent of damage lightning strikes would otherwise have caused to overhead lines, the possibility of lightning strikes was also ruled out.

1.16.4 To determine how close the longline had come to the Phase L2 conductor and an earthed object, and other possible contributing factors and effects of the accident, the following tests were conducted at the PolyU laboratory in October 2011. Representatives from CAD, Heliservices and CLP were present to witness the tests :

(a) Tests to assess the insulation breakdown strength of air

The purpose of these tests was to determine how close the longline had come to the Phase L2 conductor and an earthed object. Results of the tests have revealed that when the bare conductors were separated by a distance of approximately 20 centimetres, the insulation of the air gap could break down at an applied voltage comparable in magnitude to the FNL-TKR No. 1 circuit voltage, causing a flashover to occur between the electrodes.

It followed that if the accident longline, which was shrouded by a protective nylon fabric jacket, had moved to a distance closer than approximately 20 centimetres to the Phase L2 conductor and an earthed object at the time of the accident, the insulation of the air gap between them could break down and a flashover could occur. These test results were repeatable in the laboratory and consistent with those published in the relevant Institute of Electrical and Electronics Engineers (“IEEE”) Guide.

(b) Tests to evaluate the cause of breakdown of the Circuit Breaker and the Mission Toggle Switch

A serviceable circuit breaker of the same rating/series and a serviceable toggle switch of same type and specifications as the damaged one on the helicopter were provided by Heliservices for the conduct of these tests. The purpose was to determine how these devices were damaged as a result of the accident. Two possible causes were identified by the PolyU, i.e. by high electrical current or by high temperature.

Results of the tests have revealed that there would have been insufficient electrical current to cause the circuit breaker and mission toggle switch to fail at the time of the accident. In other words, it was more likely for these devices to have been damaged by the high temperature generated from the flashover.

(c) Tests to evaluate the insulation breakdown strength of the longline

The purpose of these tests was to evaluate the insulation breakdown strength of the longline when with or without an embedded electrical cable. To carry out the tests, a sample portion of the longline of the same type as the one used for the accident flight was obtained from the longline manufacturer. Voltage was applied across the longline sample in order to assess its insulation strength in different circumstances and conditions.

Results of the tests have revealed that if there was an electrical cable embedded inside the longline, once the external insulation was broken down, current would flow through the electrical cable with little resistance, causing it to become energized. Without the embedded electrical cable, the applied voltage would then have to break down the non-conductive material metre by metre along the length of the longline. Further, if the longline became moist or wet, even without the embedded electrical cable, it could be highly conductive, allowing current to flow freely along its length.

The test results provided useful scientific evidence on the need to review the risks associated with underslung operations in the vicinity of overhead lines. More detailed analysis is given in Section 2.5.

1.16.5 A copy of the laboratory test report and analysis produced by the PolyU is at the Annex to this report.

1.17 Organization and Management Information

1.17.1 Heliservices

1.17.1.1 Heliservices holds a Hong Kong Air Operator's Certificate ("AOC"), issued by the CAD under Article 6 of the Air Navigation (Hong Kong) Order 1995 ["AN(HK)O"], to undertake a wide variety of public transport and aerial work activities within the territorial boundaries of Hong Kong and Macau. It operates a fleet of six helicopters, including inter alia, four Aerospatiale single-engine SA 315B Lama helicopters which are used mainly for underslung operations.

1.17.1.2 The main operating base of Heliservices is located in Sek Kong, approximately 3 kilometres east of the Sek Kong Aerodrome. The base is also office to the Operations Unit which at the time of the accident, comprised one Senior Operations Officer ("SOO"), one Operations Officer and one Operations Assistant who were responsible for coordinating all helicopter tasking for the company. The company had a complement of three pilots at the time of the accident.

1.17.1.3 Heliservices' fleet was maintained by a CAD approved maintenance organization in Hong Kong. The maintenance support arrangements for Heliservices were considered satisfactory.

1.17.1.4 Heliservices had an OM in place which contained information and instructions to enable the operating staff to perform their duties. It was made available to every member of the operating staff. Prior to the accident, the last amendment made to the OM was issued on 13 December 2010.

1.17.1.5 The OM included inter alia, a specific section on "Helicopter External Load

Operations" which provided the policies, guidelines and procedures for underslung operations. It however did not contain specific procedures and safety information for the conduct of underslung operations in the vicinity of overhead lines. The risks associated with the use of the longline which incorporated a shrouded electrical cable in the vicinity of overhead lines were also not included.

1.17.1.6 Heliservices had an Emergency Response Plan ("ERP") in place to facilitate its response to emergency situations. The Plan was overseen by the Group Director of Safety and Compliance ("DSC").

1.17.2 CLP and its Work Contractors / Sub-Contractors – JPPC and Gearwin

1.17.2.1 The CLP is a major electricity generation, transmission and distribution company in Hong Kong. Its services extend to a large proportion of the Hong Kong population. Its electricity supply system consists of extensive networks of underground cables and overhead lines operating at 400 kV, 132 kV, 33 kV, 11 kV and 380/220 V.

1.17.2.2 On 17 November 2010, CLP contracted JPPC to carry out line pole foundation grouting work on the FNL-TKR No.1 Circuit. JPPC subsequently subcontracted the work to Gearwin.

1.17.2.3 At approximately 0100 hrs (0900 local time) on 3 January 2011, Gearwin ground workers arrived at the staging area for their briefing and duty assignment. After the briefing, the teams then dispersed and proceeded to the different work zones and made preparation.

1.17.2.4 The exact location of each drop-off site was selected and determined by the Gearwin ground workers on the morning of the day based on their knowledge, experience and judgement.

1.17.2.5 CLP issued a set of internal safety guidelines and documents to JPPC in September 2010. They included inter alia, a document named "General Practice for Contractors Working in Proximity to Electricity Cables and Overhead Lines ("GP")".

1.17.2.6 The GP specified that for works that are to be carried out underneath the 132 kV overhead lines, a minimum safe working distance of 3.7 metres is to be maintained at all times. No tools, equipment or apparatus which could encroach beyond the safe working distance should be used under the overhead lines.

1.17.2.7 The GP also required the contractor to refer to the latest edition of the "Code of Practice on Working near Electricity Supply Lines" issued by the Electrical and Mechanical Services Department ("EMSD"), and take all necessary precautions and measures as stipulated in the Code of Practice. More details about the requirements are given in Paragraph 1.18.

1.18 Additional information

1.18.1 The Electricity Supply Lines Protection Regulation (Chapter 406H)

1.18.1.1 Section 10(2)(b) of the Electricity Supply Lines Protection Regulation (Laws of Hong Kong, Chapter 406H) provides inter alia, that a person who carries out or causes or permits another to carry out in the vicinity of an overhead electricity line works of any kind, shall ensure that all reasonable measures are taken to prevent the occurrence of an electrical accident or an interruption to the supply of electricity arising from those works. Section 10(4) further stipulates that where the Director (of Electrical and Mechanical Services) has approved a code of practice for the requirement, then, compliance with the provisions of that code shall be deemed to constitute the taking of all reasonable steps, or the taking of all reasonable measures, as the case may be, for the purposes of that requirement (See Appendix B).

1.18.1.2 In this connection, it is noted that the EMSD has published various Codes of Practice ("COPs") which are available for viewing and download from its website. For the case in question, the applicable document would be the "*Code of Practice on Working near Electricity Supply Lines (2005 Edition)*" issued and approved by Director of Electrical and Mechanical Services in 2005 ("the applicable COP").

1.18.1.3 Upon review of the applicable COP, it is noted that "works in the vicinity of overhead lines" is defined as any works, except for blasting works, found within a horizontal distance of 9 metres from the outermost conductor of an overhead line (see Figure 4).

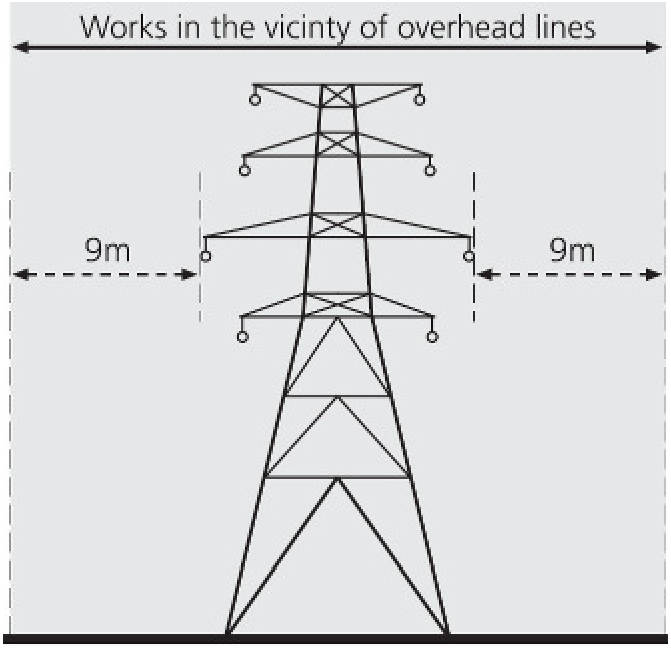


Figure 4 : Works in the vicinity of overhead lines (except blasting works) – extracted from the Code of Practice on Working near Electricity Supply Lines (2005 Edition)

1.18.1.4 The applicable COP also provides details of the reasonable steps and measures that should be taken to prevent the occurrence of an electrical accident or an interruption to the supply of electricity arising from those works. They include but are not limited to the following :

(a) Before commencement of works, the working party shall take all reasonable steps to ensure safety, which include planning the works, consulting the electricity supplier and ensuring that personnel at the works site and the appointed signaller fully understand all necessary safety precautions to be taken. (Paragraph 2.1.3 of the applicable COP refers)

(b) In the course of works in the vicinity of electricity supply lines, the working party shall adopt the reasonable measures appropriate to the nature of the works. (Paragraph 2.1.4 of the applicable COP refers)

(c) The safe system of work, together with the safety guidelines on handling accidents or emergencies, shall be effectively communicated to all persons likely to be engaged in the works in the vicinity of electricity supply lines. (Paragraph 2.1.5 of the applicable COP refers)

(d) No works shall be carried out in the vicinity of overhead lines unless a safe working distance is always maintained in such a way that damage to overhead lines can be prevented and personal safety can be safeguarded. (Paragraph 7.1.3 of the applicable COP refers)

(e) For works carried out within a 6-metre horizontal distance from the overhead lines, particularly where upward movements of plant or equipment, or construction works could encroach on the safe working distance, resulting in damage to the overhead lines and/or personal injury, additional precautions are required. (Paragraph 7.4.1 of the applicable COP refers)

1.18.2 Sequence of Major Events

1.18.2.1 Based on the evidence collected including but not limited to the accounts of the witnesses, the sequence of major events leading up to the accident and those which occurred during and after the accident on 3 January 2011 were summarized as shown at Appendix C.

1.18.3 Coordination between Heliservices and Gearwin after the Accident

1.18.3.1 After the accident, the Loadmaster and Foreman at the staging area heard a loud bang and saw black smoke ascending from Zone 3. The Foreman was then informed by a ground worker at the accident site by phone that a worker was injured and help was needed. This message was conveyed to the Loadmaster who immediately phoned and reported this information to the SOO of the Operations Unit.

1.18.3.2 According to SOO, he had instructed the Loadmaster to tell the Gearwin Foreman to call and report the accident to emergency services. The

Loadmaster did so and this instruction was overheard by the SOO who was still on the phone at the time. However, due probably to mis-communication, this message was misunderstood by the Gearwin Foreman who later said that he had heard the Loadmaster say he or his company (i.e. Heliservices) would notify emergency services. Both parties had misunderstood that the other party had taken action to call emergency services at this time.

1.18.3.3 The Gearwin Foreman then proceeded to the accident site. The Loadmaster remained at the staging area. As neither the Loadmaster nor the Operations Unit had the contact details of the Foreman, once the Foreman had left, communications between Heliservices and the Gearwin representatives on site were temporarily broken down. SOO attempted to call the Gearwin telephone numbers provided on the booking form, but in vain. Further information on the situation at the accident site was not received by Heliservices.

1.18.3.4 After a further period of some 20 to 25 minutes, Gearwin representatives called the Operations Unit to check the status of arrival of emergency services. It was only then it was realized that emergency services had yet to be called. A Gearwin representative subsequently called the “999” emergency hotline at 0649 hrs (1449 local time). This call took place 53 minutes after the accident (Paragraph 1.15.1 refers).

1.19 Useful or effective investigation techniques

1.19.1 During the course of investigation, the investigation team conducted interviews with the Pilot and witnesses to the accident, and collected evidence from the relevant parties. The flight documents, maintenance records, weather information, ATC recordings and various safety and operational procedures documents were reviewed for investigation purposes. To determine the circumstances and causes of the accident, the team also conducted further examination and tests on the underslung assembly and the various items of the affected aircraft equipment. A series of high voltage electrical tests were organized and carried out at the PolyU laboratory to evaluate the possible accident scenarios. The actions taken and techniques applied in the investigation have proven to be very effective.

2 ANALYSIS

2.1 Operation of the Flight before and after the Accident

2.1.1 Transport of the First load to Zone 3

2.1.1.1 The Pilot was properly licensed and qualified for the underslung task on 3 January 2011. Following the planned operational sequence for the day, he completed the move of the first 18 underslung loads to Zones 1 and 2 in approximately 45 minutes. He then proceeded to move the next load (i.e. the 19th load of the day) to Zone 3.

2.1.1.2 According to the Pilot, he took a north-westerly to northerly path from the staging area and flew towards Zone 3. He positioned the helicopter in between two sets of overhead lines and then tracked along this path to the drop-off site (See Figure 5).

2.1.1.3 According to his descriptions, as he flew over the area, he had continuously updated his assessment of the sites, locations of the overhead lines and houses, and how they were oriented. When he was working in Zone 2, he had already had a look at the drop-off site in Zone 3 and saw that there were no houses around it. He assessed that other than the line pole and the overhead lines associated with it, there were no crossing overhead lines or other obvious hazards.

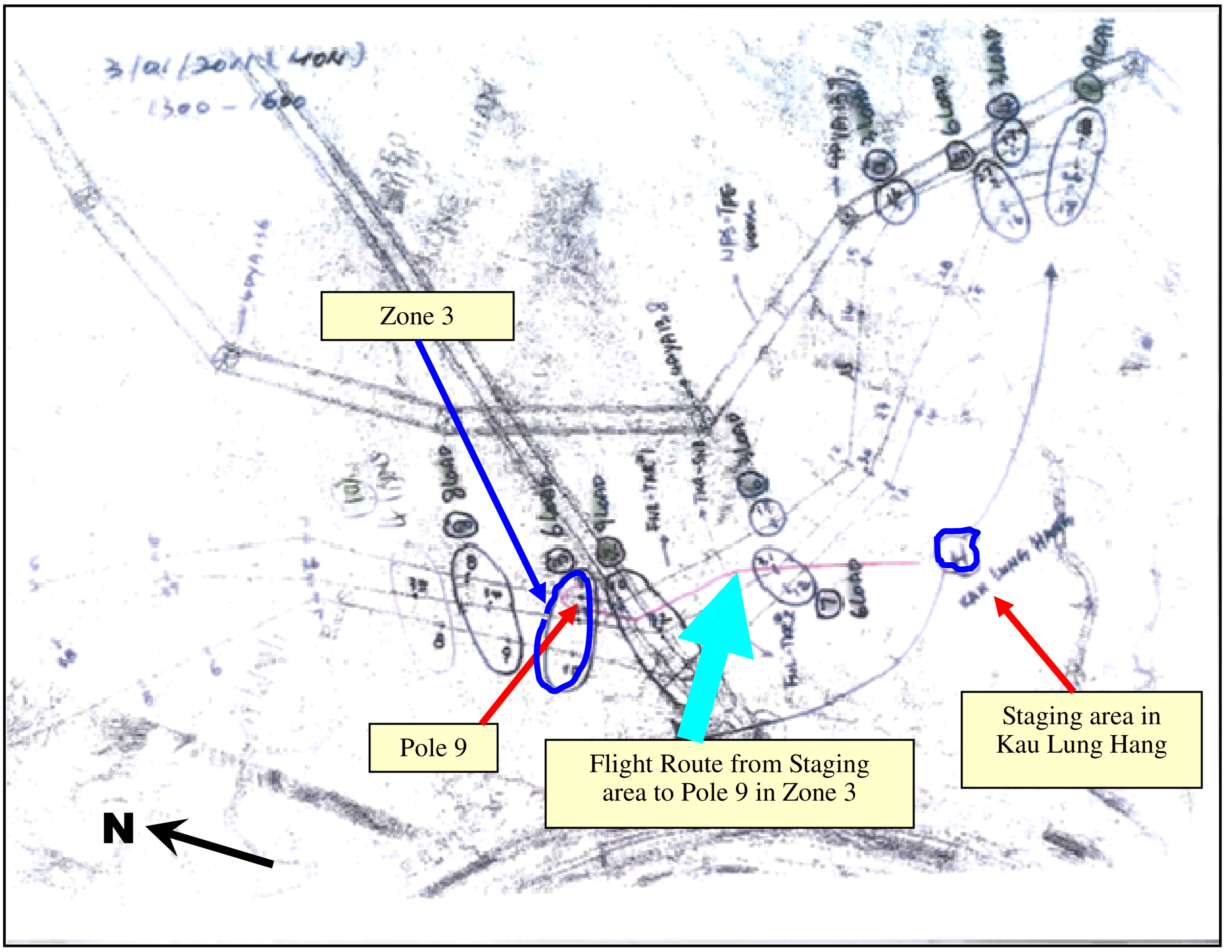


Figure 5 : The Flight Route taken by the Pilot from the Staging Area to the Accident Site (Sketch of the flight route provided by the Pilot)

2.1.1.4 As he approached west of the site, he came to a hover and visually located the drop-off point which was situated on the downhill side of Pole 9, at the bottom end of the site (see Photo 4). From there, he noticed that the drop-off site was not *really big* and that it was a clearing surrounded by vegetation. He also noticed that there was a Stay Wire on one side and three ground workers present at the site. As revealed from other evidence collected by the investigation team that there were a total of four workers at the site at the time, one worker was not sighted by the Pilot.

2.1.1.5 After the assessment, the Pilot slowly manoeuvred the helicopter towards the site. He set the helicopter up by turning the nose a little to the right to keep the line pole and overhead lines in sight. He flew the helicopter in sideways, almost at a right angle to the overhead lines, with the helicopter nose pointing north and into wind. Figure 6 is a sketch of the approach path provided by the Pilot after the accident.

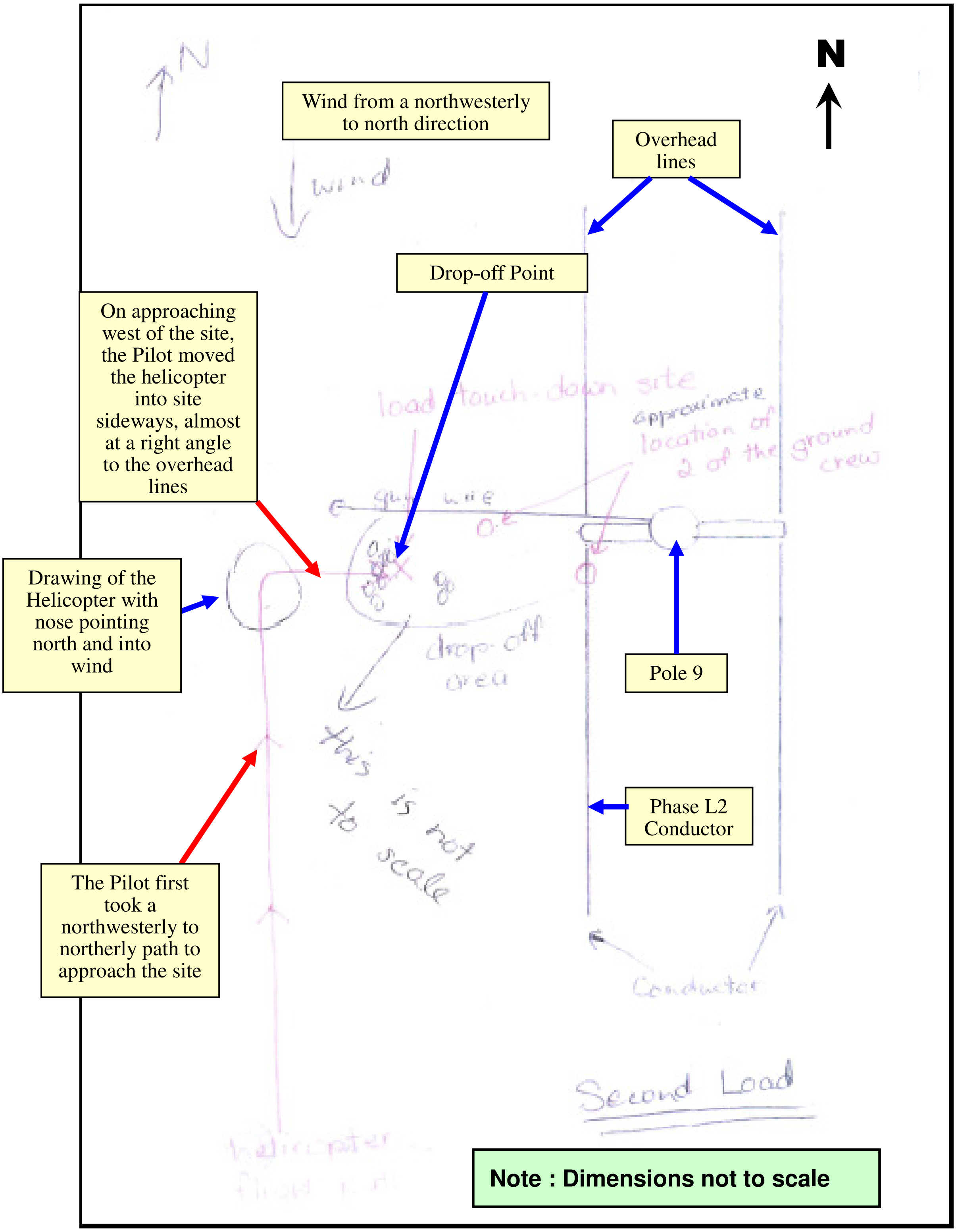


Figure 6 : The Pilot's Approach Path (Sketch provided by the Pilot)

2.1.1.6 As he approached overhead of the drop-off point, he came to a hover again. He checked to make sure that the ground workers he saw were clear of the drop-off point, and then descended vertically to set the underslung load down. According to the Pilot, after the load had touched the ground, he used the push-button located on the collective control in the cockpit to release the load electrically. The delivery of this first load to Zone 3 was uneventful.

2.1.1.7 From the site measurements and the descriptions above, the investigation team analysed that if during the unloading process, the helicopter had stayed vertically above the drop-off point with the longline hanging vertically from the helicopter, it would be at a level of approximately 19 metres above the overhead lines with the longline at a horizontal distance of around 3.9 metres from the Phase L2 conductor. Figure 7 provides a sketch of the side view of the operation with approximate dimensions.

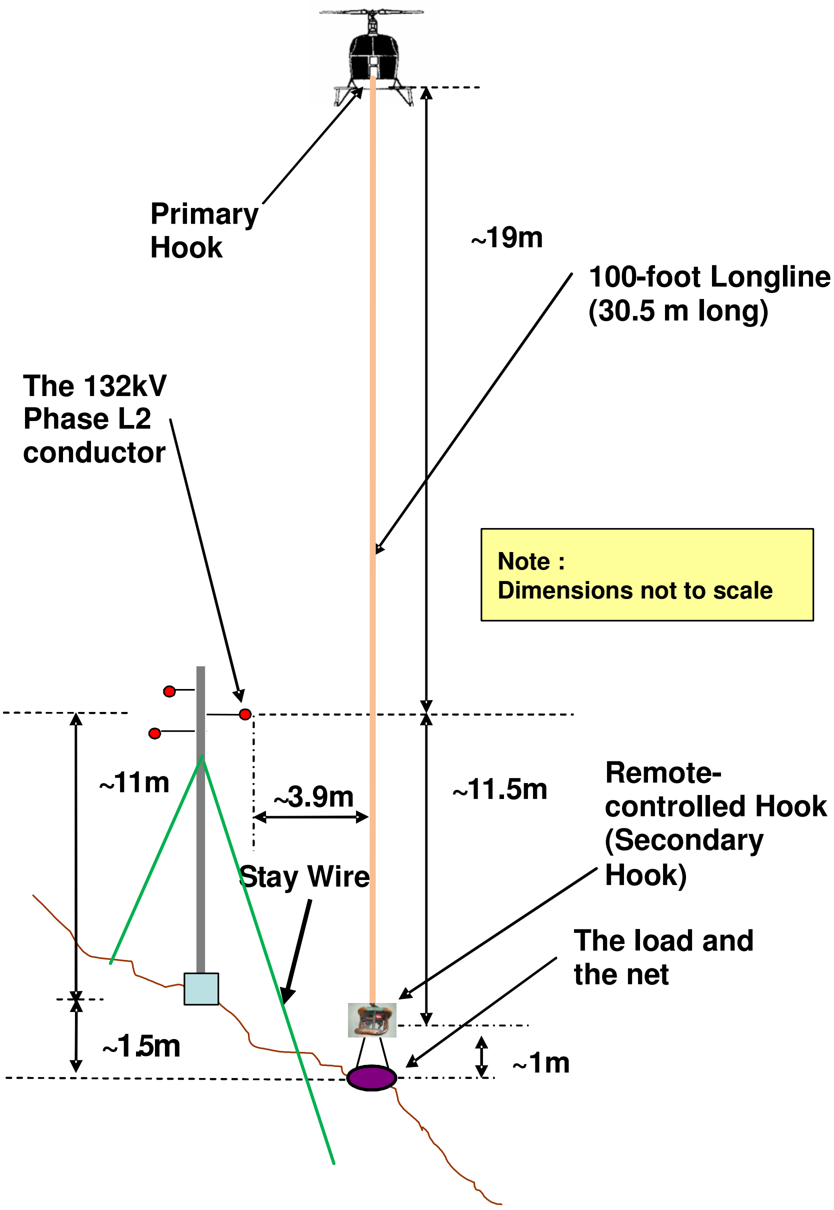


Figure 7 : A sketch of the side view of the planned unloading operation at Zone 3 with approximate dimensions

2.1.2 Transport of the Accident Load to Zone 3

2.1.2.1 After releasing the first load at Zone 3, the Pilot then returned to the staging area to collect the second load for the same site.

2.1.2.2 For this second load to Zone 3, the Pilot flew the same flight path and came to a hover west of the site in the same manner as the previous trip. This time, he only saw two ground workers at the site (as compared to three in the previous trip). He assessed that the third worker must be hiking down to the next site. He also started to look out for the empty net from the first load which the workers should have prepared ready to hook back onto the helicopter longline for return to the staging area after unloading the second load. He did not sight the empty net. He hesitated momentarily before moving the helicopter sideways towards the site.

2.1.2.3 Having made sure that the workers he saw were clear of the drop-off point, the Pilot lowered the load and set it down onto the drop-off point. The accident occurred when the helicopter was at the final stage of setting down the load.

2.1.2.4 According to the Pilot, immediately after he put down the second load, there was a momentary lapse in his memory, in terms of whether he had actually electrically released the load or not. He could not remember if he did. He sat in the hover above the load, looking down at it when he suddenly saw a bright flash. He described that *it was a flash that was sort of yellowish orangey in colour followed almost immediately by a very, very loud bang.* There was then a *really, really big cloud of some sort of brown smoke, almost like a dust ball.* As the brown cloud started to clear, he could see *wood smoke*, the two ground workers, *a whole bunch of little fires on the ground* and his *longline hanging absolutely vertical, absolutely dead still under the helicopter and straight down directly above the load* he *had just put down.* He described that *there was no movement at all in that line and it was hanging perfectly straight*, but he could see that *it was very badly damaged.* He did not know the extent of the damage but he saw that *the hook was very black* and *the line had shredded sections on it.* He also saw that *the hook was not connected to anything*, and *it was still about three feet off the ground.*

2.1.2.5 To determine the circumstances of the accident, the investigation team also reviewed and analysed the accounts of other witnesses at the site. Worker 4 who was standing near the trees at the site boundary described that the accident load had already touched the ground when the accident occurred. He also explained that as he was responsible for unhooking the load, and returning and hooking up the empty net from the previous load onto the secondary hook, he would approach the load when it was lowered to a height at which he could reach the secondary hook. However, when the height of the hook was still beyond his reach, the net containing the load that had already touched the ground suddenly dropped off the hook. A loud bang then occurred and something very bright and hot cascaded from above. Afterwards, he saw patches of fire on the ground and noticed that Worker 1 was lying on the ground with his clothing on fire. He and the other two workers quickly extinguished the fires using sand extracted from the unloaded cargo.

2.1.2.6 At the staging area which was some 500 metres from the accident site, the Loadmaster and Foreman also heard the loud bang and saw black smoke ascending from Zone 3. They also sighted the helicopter as it departed the site heading towards the direction of Sek Kong.

2.1.2.7 These witness accounts together with other evidence collected provided consolidated information on the circumstances of the accident and the operational status of the flight before and after the accident.

2.2 Analysis of the Accident Flight

2.2.1 Based on the information given above, it is analysed that at the time of the accident, the longline had come close enough to the nearby Phase L2 conductor and an earthed object (which could be tree branches, the ground or any other objects connected to ground) to cause a flashover to occur. This is supported by the test results described in Paragraph 1.16.4 (a) that if the accident longline, which was shrouded by a protective nylon fabric jacket, had moved to a distance closer than approximately 20 centimetres to the Phase L2 conductor and an earthed object at the time of the accident, the insulation of the air gap between them could break down and a fault current could be triggered to flow from the conductor through the low voltage cable inside the longline and the remote-controlled hook to the earthed object, causing a short circuit and flashover to occur. Other possible causes of short circuit including transient surges of electricity in the CLP's electrical system and lightning strikes were also considered, however they were ruled out.

2.2.2 The analysis in Paragraph 2.1.1.7 further shows that if the helicopter had stayed vertically above the drop-off point with the longline hanging vertically straight down from the helicopter, the longline would have been at a horizontal distance of about 3.9 metres from the Phase L2 conductor (see Figure 7) and the accident and flashover would not have occurred.

2.2.3 There were no burn marks on the cargo net. The "8-shaped" hook (see Photo 18) which connected the cargo net to the helicopter remote-controlled hook was also found intact and undamaged. These indications show that the cargo net and the "8-shaped" hook had already been released and were disconnected from the secondary hook before the flashover. This finding is consistent with the descriptions of Worker 4 (see Paragraph 2.1.2.5).

2.2.4 From the alignment of the overhead lines, location, size and orientation of the drop-off site, manoeuvres of the helicopter and other environmental factors, the investigation team estimated that one or a combination of the following possible circumstances might have occurred causing the longline to swing, or move to a distance closer than 20 centimetres to the Phase L2 conductor and an earthed object :

(a) The helicopter was not directly over the load on the ground, causing the longline to swing when the load was released or inadvertently released;

(b) The helicopter was not in steady hover when the load was released or inadvertently released and the movement of the helicopter had caused the longline to swing;

(c) A gust of wind had caused inadvertent movement of the helicopter and the longline to swing, although the weather report and the observation of the Pilot on the day indicated that the wind was not strong;

(d) Movement of the helicopter towards the Phase L2 conductor either by mishandling, gust of wind or loss of pilot concentration after the load was released or inadvertently released; and / or

(e) The load fell over the slope upon touching the ground and it pulled the longline at an angle away from the overhead line. When it was then released, it caused the longline to swing towards the Phase L2 conductor.

2.2.5 When the longline, live overhead line and earthed object had come close enough to cause the insulation of the air to break down, a fault current would be triggered to flow from the conductor through the low voltage cable inside the longline and the remote-controlled hook to the earthed object.

2.2.6 If the current went through the tree branches, the tree branches could catch fire. When the current reached the ground, it could raise the potential of the local ground and force a current to flow from the ground towards Pole 9, then up to the aerial earth wire at the top of the pole. This explained the burn marks and damage mentioned in Sections 1.3 and 1.4 of this report.

2.2.7 From the flight operations perspective, the Pilot was an experienced and skilled pilot in underslung operations and there was no evidence to suggest that the performance of the Pilot had been affected by fatigue, alcohol, drugs and/or medication at the time of the accident. However, bearing in mind that the helicopter was a moving system and it was susceptible to unsteady movement during the unloading operation, when it was hovering over the site with the drop-off point and the Phase L2 conductor only approximately 3.9 metres apart, a swing of only one degree (1°) of the 100-foot longline towards the overhead lines would have caused the longline to move more than 0.3 metres closer to the overhead lines, encroaching on the minimum safe working distance of 3.7 metres as stipulated by the CLP in its GP document (see Section 1.17.2.6).

2.2.8 From the safety rule compliance perspective, it is apparent that the published requirements, including those in the CLP GP and in the applicable COP issued by EMSD on working near electricity supply lines, had not been strictly followed. The selected drop-off site was too close to the overhead lines and the precautionary measures that should have been taken for operating and working in the vicinity of overhead lines were insufficient.

2.2.9 Furthermore, the investigation team also noted that there was a general lack of awareness and understanding of the risks associated with underslung operations in the vicinity of overhead lines by the working parties. Although Heliservices had in its OM a specific section on “Helicopter External Load Operations”, no specific procedures and safety information for the conduct of underslung operations in the vicinity of overhead lines were given in the OM. The risks associated with the use of the longline which incorporated a shrouded electrical cable in the vicinity of overhead lines were also not mentioned. Inadequate risk assessment had been undertaken before the operation.

2.2.10 In this connection, it should be noted that according to the longline User Instructions Manual issued by the longline manufacturer, “*use of this equipment in areas with environmental hazards may require additional precautions to prevent injury to the user or damage to the equipment. Hazards may include, but are not limited to: heat, chemicals contamination, electrical fields, electrostatic discharges, moving machinery, corrosion, gases and sharp edges.*” Further clarification provided by the manufacturer after the accident also indicates that anyone working in the energized wire environment should NOT use a remote hook with an electrical wire running alongside the longline.

2.2.11 After the accident, the Pilot departed the accident site. As the accident had no direct impact on the flight control system, there was no immediate effect on the safety or control and operation of the helicopter.

2.3 Aircraft Airworthiness and Maintenance

2.3.1 The helicopter had a valid Certificate of Airworthiness at the time of the accident. The aircraft technical records also indicated that the helicopter had been maintained in accordance with the CAD approved maintenance schedule and there had not been any significant airworthiness issues.

2.3.2 A review of the Aircraft Log Book also indicated that the helicopter had no outstanding defects prior to the accident flight. In other words, the helicopter was fully serviceable in all respects prior to the accident.

2.3.3 The underslung assembly was checked and maintained in accordance with the requirements of the Aircraft Flight Manual Supplements, manufacturer and relevant authorities prior to use.

2.4 Damage to Aircraft Equipment

2.4.1 After the accident, several items of the aircraft equipment were found to have been damaged. They included the ADF navigation equipment, aircraft transponder aircraft radio equipment, and the circuit breaker and the mission toggle switch for the remote-controlled hook. To determine the cause of damage, the electrical wiring of the longline and remote-controlled hook in conjunction with the helicopter electrical system was analysed (See Appendix D).

2.4.2 From the wiring diagram, it is noted that the 28 V power source inside the cockpit was connected to various devices through a 5 ampere (A) circuit breaker and a mission toggle switch as shown in Appendix D. When the 5 A circuit breaker and toggle switch were closed, current from the 28 V DC Bus would flow into the Junction Box to operate the solenoid control coil at the remote-controlled hook when the Pilot Collective Pitch Lever Protected Switch was pressed.

2.4.3 Expert advice from the PolyU indicates that if there were high voltages or temperature originating from the longline and remote-controlled hook, the current or heat energy could flow in the reverse direction to cause damage to the electrical circuit of the helicopter.

2.4.4 It also follows that if the longline used had no wiring (or conductive material) connected directly to the helicopter electrical system, the aircraft equipment would not have been affected. To safeguard the operations of the helicopter, longlines which incorporate a shrouded electrical cable should not be used in the vicinity of overhead lines unless a detailed and comprehensive risk assessment has been carried out and necessary procedures, such as switching off the high voltage overhead lines in that area, have been implemented.

2.5 Insulation Strength of the Longline

2.5.1 As part of the investigation, the insulation strength of the longline used was also tested and assessed in different circumstances and conditions.

2.5.2 From the results as described in Section 1.16.4 (c) and the Annex to this report, it was shown that if there was an electrical cable embedded inside the longline, once the external insulation was broken down, current would flow through the electrical cable with little resistance, causing it to become energized. Without the embedded electrical cable, the applied voltage would then have to break down the non-conductive material metre by metre along the length of the longline. Further, if the longline became moist or wet during operations due to moisture in the air, even without an embedded cable, it could also be highly conductive, allowing current to flow freely along its length.

2.5.3 It therefore follows that whether or not the longline incorporates an embedded electrical cable, when a helicopter is carrying out an underslung operation in the vicinity of high voltage overhead lines, due safety precautions should be undertaken to ensure the safe operation of the helicopter and to prevent the occurrence of an electrical accident. A detailed and comprehensive risk assessment should be carried out prior to the conduct of all underslung operations in the vicinity of overhead lines.

2.6 Communications and Coordination Procedures

2.6.1 Communications between the Pilot and ATC were satisfactory until after the accident when communications broke down as a result of the damage to the aircraft radio equipment.

2.6.2 After the accident, the Pilot also made several attempts to communicate with the Loadmaster on the company VHF frequency using the aircraft radios. However, no radio contact could be established as a result of the damage to the aircraft radio equipment.

2.6.3 Between Heliservices and Gearwin, it is apparent that inadequate communication and coordination procedures had been established, especially in case of an emergency. As neither the Loadmaster nor the Operations Unit had the telephone contact details of the Foreman or the workers at the drop-off site, communications between Heliservices and the Gearwin representatives on site were temporarily broken down once the Loadmaster and/or the Gearwin Foreman had left the staging area after the accident. Further information on the situation at the accident site was not received by Heliservices. The temporary breakdown in communication between the two parties had caused a significant delay in the reporting of the accident to emergency services. This in turn had delayed the rescue action and medical treatment of the injured workers.

2.6.4 In terms of coordination arrangements, it was further noted that there were inadequate on-site control procedures between Heliservices and Gearwin to ensure that all the ground workers who would hook and unhook loads from a Heliservices helicopter held a valid ground safety training course ID card. Consequently, Worker 4, whose ground safety training qualification had lapsed, was inappropriately assigned to return and hook up the empty nets onto the helicopter secondary hook after delivery of the second load. This was contrary to the company's operational and safety procedures.

2.7 Emergency Handling by Heliservices

2.7.1 The DSC was informed of the accident by SOO at approximately 0610 hrs (1410 local time). According to the ERP of Heliservices, an Emergency Operations Centre ("EOC") as led by the DSC should be set up at the Sek Kong base in the event of an accident involving a company owned or managed aircraft resulting in extensive damage to the aircraft or property, or loss of life or serious injury.

2.7.2 However, the EOC was not set up to control the emergency situation. The emergency response checklists had not been deployed for use. The procedures of the ERP had not been followed and this may also be one of the contributing factors to the significant delay in the calling of emergency services.

2.8 Survivability

2.8.1 As a result of the accident, the two ground workers (Worker 1 and Worker 3) who were standing closest to the load drop-off point sustained varying degrees of burn injuries.

2.8.2 Both workers were equipped with PPE, which included inter alia, a safety helmet, safety shoes and work gloves. The PPE was burnt and damaged after the accident. Had PPE not been worn, the extent of injuries to the workers would have been more severe.

2.9 Emergency and Rescue Services

2.9.1 On receipt of the emergency alert call, emergency rescue services were promptly deployed by the Fire Services Department to the nearest vehicle staging area on Tai Wo Service Road East at the outskirts of Kau Lung Hang Shan.

2.9.2 As the accident site was located on the hillside of Kau Lung Hang Lo Wai which was not accessible by road vehicles, the emergency rescue crew had to proceed uphill on foot. It took the crew approximately 20 minutes to complete the walk.

2.9.3 On arrival at the accident site, the emergency rescue crew quickly performed first aid treatment on the seriously injured worker (Worker 1). Both injured workers were then promptly conveyed to hospitals where they received further medical treatment.

2.9.4 The emergency response and level of attendance of the emergency rescue service personnel was efficient and effective.

2.10 Safety Improvement Actions taken by Heliservices and CLP after the accident

2.10.1 After the accident, Heliservices immediately suspended the use of longlines which incorporated a shrouded electrical cable. It also suspended all of its underslung operations in the vicinity of high voltage overhead electricity lines.

2.10.2 During the investigation period, Heliservices had reviewed and incorporated new guidelines and procedures in its OM and company SOPs to enhance the safety of its underslung operation and coordination procedures and arrangements with other parties. They included inter alia, the following :

(a) Incorporation of a new procedure in the OM for "Flight in the Vicinity of Overhead Lines"

This new procedure provides that when conducting underslung operations near overhead lines, no portion of the helicopter or load shall come within 9 metres of an energized conductor.

(b) Incorporation of a new procedure in the OM on longline selection

This new procedure provides that the type of longline to be used should be dictated by the requirements of the task and it should be carefully considered by the Commander of the flight.

(c) Revised duties and enhanced training for Loadmaster

A new Loadmaster Checklist has been introduced. Prior to the commencement of all underslung operations, Loadmasters shall annotate the contact details of the ground personnel on the Loadmaster Checklist, including those primary contact persons at the staging area and all other drop-off sites, to facilitate communication and coordination. They should also ensure that the ground safety training ID cards of the ground personnel at the staging area are current. The training syllabus for Loadmasters has been enhanced accordingly.

(d) Introduction of a new guideline in the OM on pick-up and drop-off site selection

The new guideline specifies that when selecting a pick-up/drop-off site, the safety distances from overhead lines must be adhered to.

(e) Introduction of new procedures in the OM to enhance the safety of ground personnel and enhanced training for ground personnel

The new safety procedures stipulate that during the unloading process, all ground personnel should remain clear of the drop-off point until the load is situated in a stable hover over the aiming point, at not more than chest height from ground. They may then approach the load to unhook and if needed, re-hook another load at this point. They should also ensure that they are positioned within the visual range of the pilot. The training syllabus for ground personnel has been enhanced accordingly.

(f) Revised Emergency / Accident / Incident Response Procedures in the OM

The new procedures provide that in the event of an accident or incident on site causing injury to personnel, the Loadmasters who witness or are advised of an injury requiring medical attention are to dial "999" on their mobile phone before calling the Operations Unit. When the immediate alerting actions are completed, personnel should then refer to the ERP.

2.10.3 In addition to Heliservices, CLP has also conducted a comprehensive review of the safety requirements and procedures for helicopter operations near overhead lines in consultation and coordination with Heliservices and other concerned parties. The number of personnel to be required at the sites, roles and responsibilities of each working party, type of longlines to be used for the different tasks, work procedures and safe work practices to follow, requirements for pre-flight risk assessment, working clearance from overhead lines, etc. are now given in greater detail in the updated procedures document, namely "*Procedures for Work Crew Carrying and External Load Operation by Helicopters" (Revision No. 6) dated 1 January 2012*.

3 CONCLUSIONS

3.1 Findings

3.1.1 The underslung operation planned for the day of the accident was to move 57 netted loads of building materials from the designated staging area to 10 different work zones situated along the FNL-TKR No. 1 Circuit.

3.1.2 The Pilot was properly licensed and qualified for the underslung task. He had previous experience working near the same set of overhead electricity lines before the accident.

3.1.3 The Pilot made pre-flight preparations which included a weather check, a study of the job description and routes to be flown prior to the commencement of the underslung operation.

3.1.4 There was no evidence to suggest that the performance of the Pilot had been affected by fatigue, alcohol, drugs and/or medication at the time of the accident.

3.1.5 The flight was conducted in daylight under VFR and the helicopter was equipped with appropriate navigation equipment for the flight.

3.1.6 At the time of the accident, the weather over the northeastern part of the New Territories was generally cloudy with light to moderate wind coming from a northerly direction.

3.1.7 The helicopter had a valid Certificate of Airworthiness and was maintained in accordance with the CAD approved maintenance schedule.

3.1.8 The helicopter had no outstanding defects prior to the accident flight and was fully serviceable in all respects.

3.1.9 The underslung assembly was checked and maintained in accordance with the requirements of the Aircraft Flight Manual Supplements, manufacturer and relevant authorities prior to use.

3.1.10 The weight and balance of the helicopter was within limits.

3.1.11 Communications between the Pilot and ATC were satisfactory until after the accident when communications broke down as a result of the damage to the aircraft radio equipment.

3.1.12 The operation involving the move of the first 19 loads to Zones 1, 2 and 3 was uneventful. The accident occurred when the helicopter was at the final stage of setting down the 20th load of the day at the drop-off point in Zone 3 located downhill of Pole 9 of the FNL-TKR No. 1 Circuit. A flashover occurred between the helicopter longline and a live overhead line of the FNL-TKR No. 1 Circuit. The fire generated from the flashover and the burning fragments of the longline scattered over the accident site. Two ground workers suffered burn injuries.

3.1.13 After the accident, the longline and remote-controlled hook were found to have been damaged. The length of the damaged section of the longline was consistent with the height of the overhead lines at Pole 9 of the FNL-TKR No. 1 Circuit.

3.1.14 Besides the longline, several items of the aircraft equipment on board the helicopter were found to have been damaged.

3.1.15 There was a momentary lapse in the Pilot’s memory, in terms of whether he actually electrically released the load or not, before the accident.

3.1.16 Evidence has shown that the cargo net and the “8-shaped” hook had already been released and were disconnected from the secondary hook before the flashover.

3.1.17 Research and test results have revealed that if at the time of the accident, the accident longline had moved to a distance closer than approximately 20 centimetres to the live overhead line and an earthed object, a short circuit and flashover could occur. Other possible causes of short circuit were also considered, however they were ruled out.

3.1.18 The investigation team estimated that one or a combination of possible circumstances might have occurred causing the longline to swing, or move to a distance closer than 20 centimetres to the live overhead line and an earthed object.

3.1.19 Results of the investigation have revealed that the selected drop-off site was too close to the overhead lines. The published requirements, including those in the CLP GP and in the applicable COP issued by EMSD on working near electricity supply lines, had not been strictly followed.

3.1.20 Heliservices OM did not contain specific procedures and safety information for the conduct of underslung operations in the vicinity of overhead lines. The risks associated with the use of the longline which incorporated a shrouded electrical cable in the vicinity of overhead lines were also not mentioned.

3.1.21 After the accident, the Pilot departed the site without the load and flew back to the company base at Sek Kong.

3.1.22 Research and test results have shown that whether or not the longline incorporates an embedded electrical cable, when a helicopter is carrying out an underslung operation in the vicinity of high voltage overhead lines, due safety precautions should be undertaken to ensure the safe operation of the helicopter and to prevent the occurrence of an electrical accident.

3.1.23 The accident was reported to the emergency and rescue services (the '999' hotline) by a Gearwin representative, 53 minutes after the accident.

3.1.24 The on-site coordination and communication procedures between Heliservices and Gearwin were inadequate, resulting in mis-communication and a significant delay in the reporting of the accident to emergency services.

3.1.25 There were inadequate on-site control procedures to ensure that all the ground workers who would hook and unhook loads from a Heliservices helicopter had received the necessary ground safety training.

3.1.26 The procedures of the ERP of Heliservices had not been followed and the EOC was not set up to control the emergency situation after the accident.

3.1.27 Had PPE not been worn, the extent of injuries to the workers would have been more severe.

3.1.28 The emergency response and level of attendance of the emergency rescue service personnel was efficient and effective.

3.1.29 Subsequent to the accident, Heliservices had reviewed its safety requirements for helicopter operations near overhead lines and enhanced its coordination procedures and arrangements with other parties.

3.2 Cause

3.2.1 As the helicopter flew and hovered close to the overhead lines during the underslung operation, the longline had come close enough to a live overhead line and an earthed object to cause a fault current to flow from the live overhead line to the earthed object, triggering a flashover. The flashover lasted for a number of milli-seconds and resulted in a fire and a loud bang, causing damage and injuries. (Paragraph 2.2)

3.3 Contributing Factors

3.3.1 The published safety requirements on working near electricity supply lines had not been strictly followed. The selected drop-off site was too close to the overhead lines and the precautionary measures that should have been taken for operating and working in the vicinity of overhead lines were insufficient. (Paragraph 2.2.8)

3.3.2 There was a general lack of awareness and understanding of the risks associated with underslung operations in the vicinity of overhead lines by the working parties. Inadequate risk assessment had been undertaken before the operation. (Paragraph 2.2.9)

4 SAFETY RECOMMENDATIONS

4.1 Recommendations

4.1.1 During the course of investigation, the investigation team issued the following Safety Recommendation in March 2011 :

Recommendation 2011-2

"*It is recommended that when operating in the vicinity of overhead high voltage electricity lines, the use of any underslung cable assemblies by Heliservices on Aerospatiale SA 315B LAMA helicopters, which consists of electrical conducting material, should be suspended until completion of the investigation or a further recommendation is issued.*"

4.1.2 Having regard to the results of investigation, the following Safety Recommendation 2014-1 is hereby issued which will supersede Recommendation 2011-2 with immediate effect :

Recommendation 2014-1

"*It is recommended that prior to operating in the vicinity of overhead electricity lines, helicopter operators should conduct a detailed and comprehensive risk assessment, in conjunction with the electricity supplier and relevant parties involved.*" (Paragraphs 2.4.4, 2.5.3 and 3.3.2)

4.2 Safety Actions Already Implemented

4.2.1 A detailed list of the safety actions already implemented by Heliservices and CLP are given in Paragraph 2.10.

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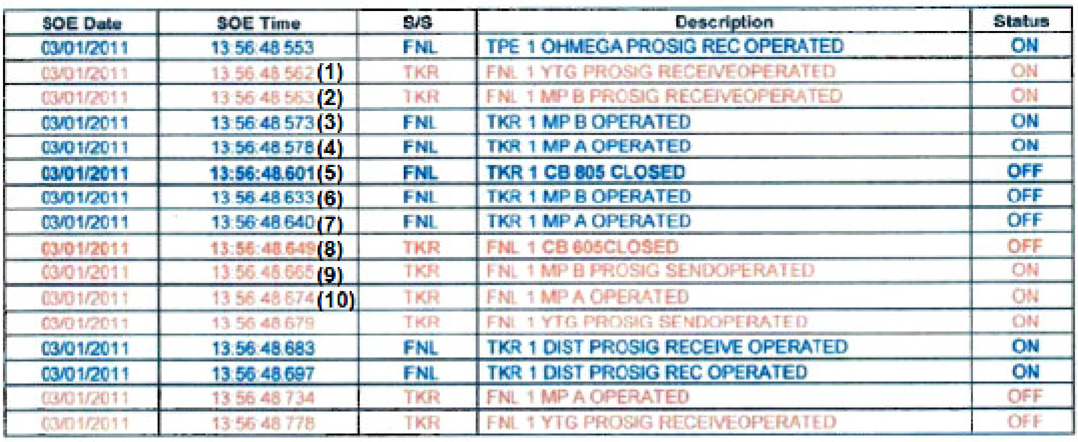
FNL-TKR No. 1 Circuit Fault

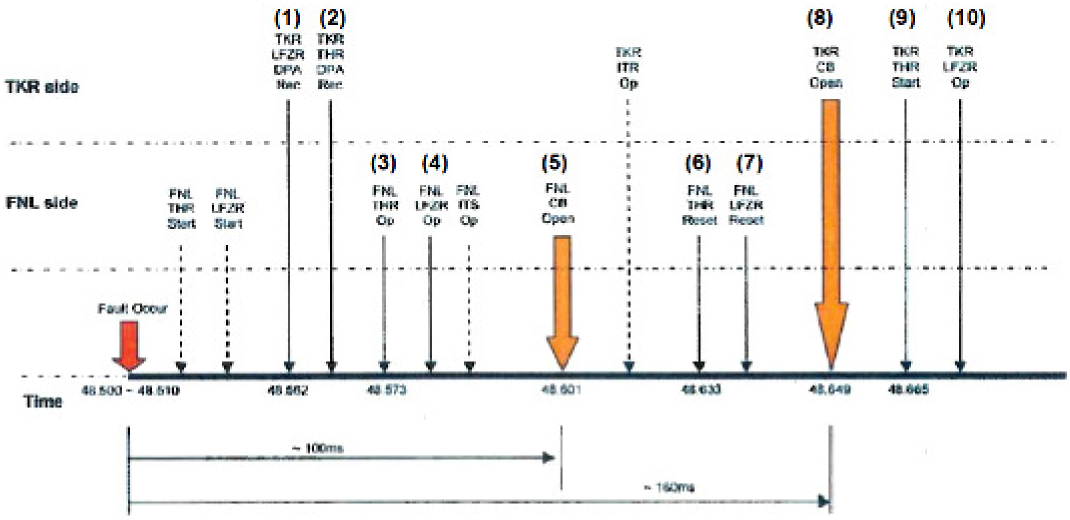
Date : **3 January 2011**
Time : **0556 hrs (1356 local time)**
Faulty Phase : **L2**

Sequence of Event

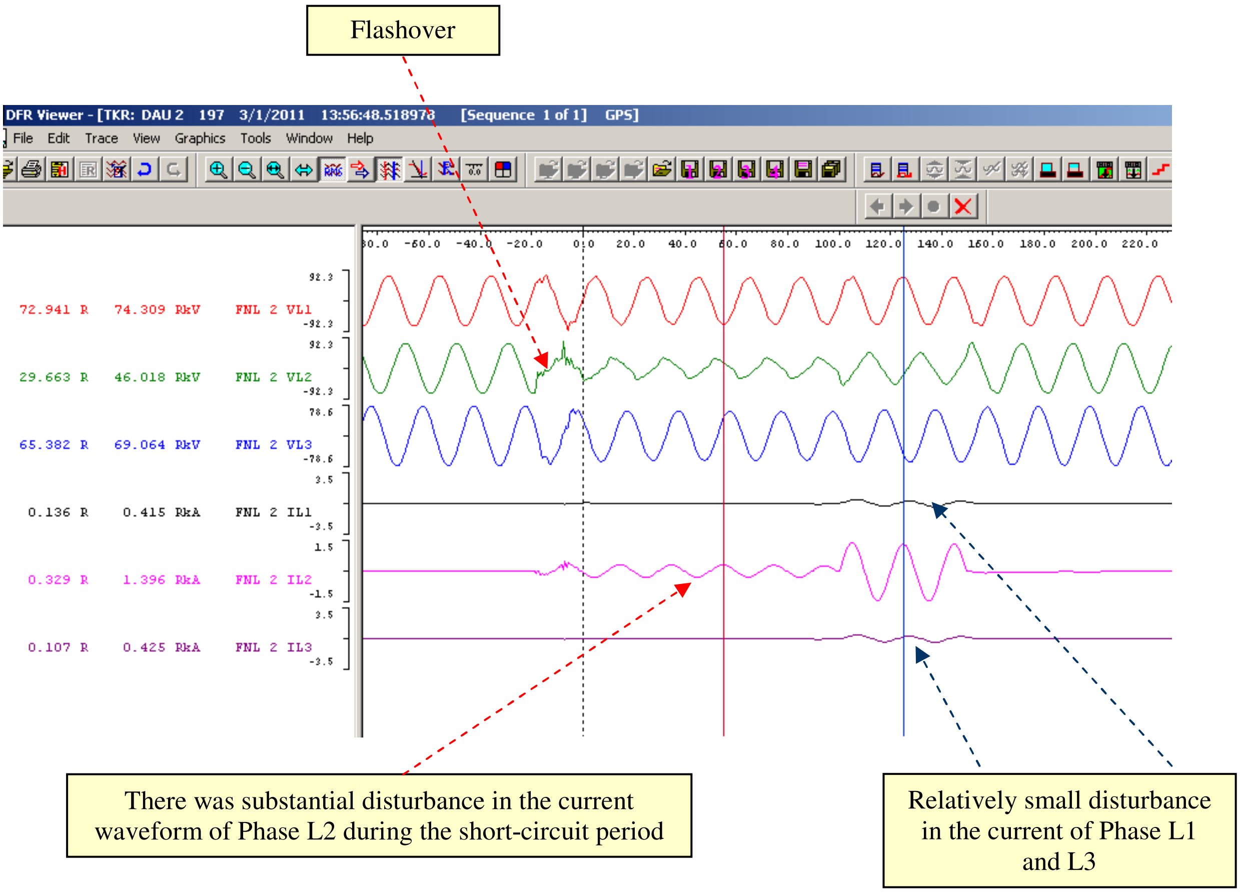


SOE Date	SOE Time	S/S	Description	Status
03/01/2011	13:56:48.553	FNL	TPE 1 OHMEGA PROSIG REC OPERATED	ON
03/01/2011	13:56:48.562 (1)	TKR	FNL 1 YTG PROSIG RECEIVEOPERATED	ON
03/01/2011	13:56:48.563 (2)	TKR	FNL 1 MP B PROSIG RECEIVEOPERATED	ON
03/01/2011	13:56:48.573 (3)	FNL	TKR 1 MP B OPERATED	ON
03/01/2011	13:56:48.578 (4)	FNL	TKR 1 MP A OPERATED	ON
03/01/2011	**13:56:48.601 (5)**	**FNL**	**TKR 1 CB 805 CLOSED**	**OFF**
03/01/2011	13:56:48.633 (6)	FNL	TKR 1 MP B OPERATED	OFF
03/01/2011	13:56:48.640 (7)	FNL	TKR 1 MP A OPERATED	OFF
03/01/2011	13:56:48.649 (8)	TKR	FNL 1 CB 605CLOSED	OFF
03/01/2011	13:56:48.665 (9)	TKR	FNL 1 MP B PROSIG SENDOPERATED	ON
03/01/2011	13:56:48.674 (10)	TKR	FNL 1 MP A OPERATED	ON
03/01/2011	13:56:48.679	TKR	FNL 1 YTG PROSIG SENDOPERATED	ON
03/01/2011	13:56:48.683	FNL	TKR 1 DIST PROSIG RECEIVE OPERATED	ON
03/01/2011	13:56:48.697	FNL	TKR 1 DIST PROSIG REC OPERATED	ON
03/01/2011	13:56:48.734	TKR	FNL 1 MP A OPERATED	OFF
03/01/2011	13:56:48.778	TKR	FNL 1 YTG PROSIG RECEIVEOPERATED	OFF

Time Chart



Fault Chart as recorded in the TKR Sub-station



There was substantial disturbance in the current waveform of Phase L2 during the short-circuit period

Relatively small disturbance in the current of Phase L1 and L3

Extracts from the Electricity Supply Lines Protection Regulation – Section 10 (Laws of Hong Kong, Chapter 406H)

Section:	10	**Requirements relating to works in vicinity of electricity supply lines**	L.N. 362 of 2000	01/04/2001

Works in Vicinity of Electricity Supply Lines

(1) A person shall not-

(a) carry out or cause or permit another to carry out in the vicinity of an underground electricity cable any works which are below ground level; or

(b) carry out or cause or permit another to carry out in the vicinity of an overhead electricity line works of any kind,

unless before the works are begun all reasonable steps have been taken to ascertain the existence within the proposed works site and its vicinity of any such underground electricity cable and its alignment and depth or of any such overhead electricity line and its alignment, distance from the ground and voltage, as the case may be.

(2) A person who-

(a) carries out or causes or permits another to carry out in the vicinity of an underground electricity cable any works which are below ground level; or

(b) carries out or causes or permits another to carry out in the vicinity of an overhead electricity line works of any kind,

shall ensure that all reasonable measures are taken to prevent the occurrence of an electrical accident or an interruption to the supply of electricity arising from those works.

(3) For the purposes of subsection (1) as it applies in relation to works in the vicinity of an underground electricity cable, and without affecting the generality of that subsection, reasonable steps shall not be regarded as having been taken unless a competent person has undertaken an investigation for the purpose of ascertaining the existence within the proposed works site and its vicinity of any such underground electricity cable and its alignment and depth and has provided a written report of his findings as to those matters.

(4) Subject to section 11(7), where the Director has approved a code of practice for any of the requirements of paragraph (a) or (b) of subsection (1) or (2), then, subject to subsection (3), compliance with the provisions of that code shall be deemed to constitute the taking of all reasonable steps, or the taking of all reasonable measures, as the case may be, for the purposes of that requirement.

(5) A competent person who undertakes an investigation to ascertain the existence, alignment and depth of an underground electricity cable-

(a) shall not delegate the function and duty of the investigation to another person;

(b) may carry out the investigation with the assistance of any other persons, but such persons shall be directly supervised by that competent person at the proposed works site in the course of the investigation;

(c) shall carry out the investigation in a manner that does not cause damage to, or impair the operation of, the underground electricity cable; and

(d) shall provide the person requesting the investigation with a written report of his findings as to that matter.

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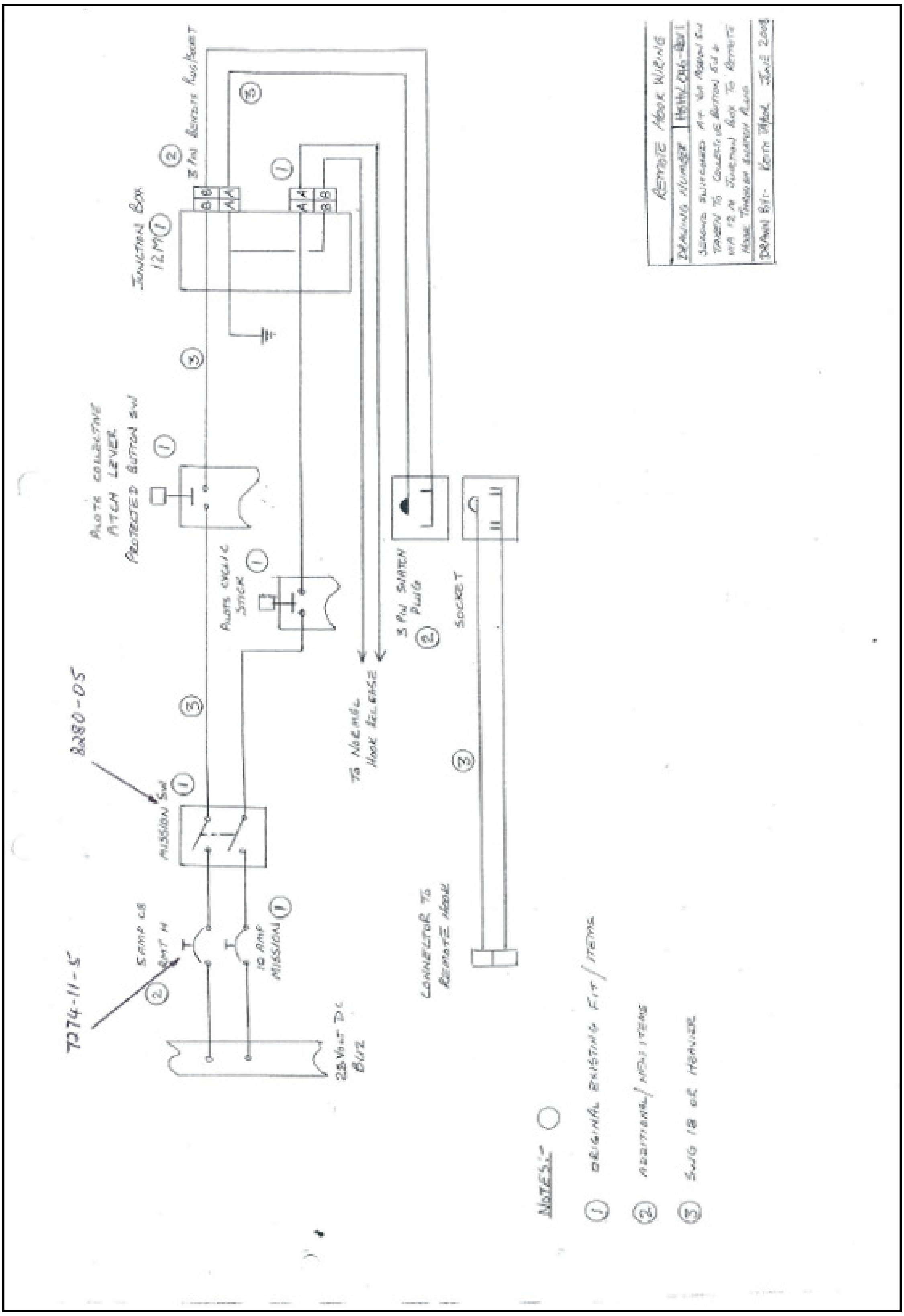
Sequence of Major Events –
<u>Leading up to the accident and those which occurred during and after the accident on 3 January 2011</u>

Time	Event Description
30 December 2010	
-	JPPC submitted a helicopter booking request to Heliservices for underslung operation to be conducted between 1300 and 1600 local time on 3 January 2011. The location map and planned operational sequence were also submitted.
3 January 2011	
Approx. 0100 hrs (0900 LT)	Gearwin workers arrived at the staging area to prepare for the day's loading and unloading work.
Approx. 0300 hrs (1100 LT)	Four Gearwin workers arrived at Zone 3. They determined the exact location of the drop-off site, cleared up the area and made preparation for the unloading operation.
Before 0500 hrs (1300 LT)	Heliservices Loadmaster arrived at the staging area.
Approx. 0510 hrs (1310 LT)	Helicopter took off from the Sek Kong base and flew to Kau Lung Hang Lo Wai for the underslung operation.
0513 hrs (1313 LT)	Helicopter advised ATC that it had commenced underslung operation.
Approx. 0550 hrs (1350)	Helicopter completed the move of the first 18 netted loads from the staging area to Zones 1 and 2 which took approximately 45 minutes. The Pilot then proceeded to move the next load (i.e. the 19th load of the day) to Zone 3. The four Gearwin workers at Zone 3 were assigned different responsibilities to assist in the unloading operation on ground. The delivery of the first load to Zone 3 was uneventful.
Approx. 0555 hrs (1355 LT)	Helicopter flew to Zone 3 again with the 20th load of the day. It moved towards the drop-off site, lowered the load and set it down onto the drop-off point.

Time	**Event Description**
Approx. 0556 hrs (1356 LT)	A flashover occurred between the helicopter longline and a live overhead line of the FNL-TKR No. 1 Circuit. The fire generated from the flashover and the burning fragments of the longline scattered over the accident site. Two ground workers (Worker 1 and Worker 3) who were standing closest to the drop-off point suffered burn injuries.
	Heliservices Loadmaster and Gearwin personnel at the staging area also heard the bang. They saw black smoke ascending from Zone 3.
	The 132 kV overhead line circuit between FNL and TKR was tripped.
Approx. 0557-0600 hrs (1357-1400 LT)	The Pilot made several attempts to communicate with the Loadmaster using the two aircraft radios on board (i.e. COM1 and COM2) and also with ATC on COM 1. However, no radio contact could be established as a result of the damage to the aircraft radio equipment.
Approx 0605 hrs (1405 LT)	Helicopter returned and landed at the Sek Kong base.
0649 hrs (1449 LT)	A Gearwin representative who arrived at the site after the accident, made a call to the '999' hotline alerting emergency services to the accident.
Approx. 0655-0700 hrs (1455-1500 LT)	First emergency rescue crew arrived at the vehicle staging area located nearest to the accident site at Tai Wo Service Road East.
Approx. 0720 hrs (1520 LT)	The emergency rescue crew arrived at the accident site. They immediately performed first aid treatment to Worker 1 who was seriously injured.
Approx. 0730-0755 hrs (1530-1555 LT)	Worker 1 was conveyed downhill by the emergency rescue crew. Worker 3 who suffered minor injuries also proceeded downhill in the company of the emergency rescue crew.
Approx. 0755 hrs (1555 LT)	Worker 1 was taken to the Prince of Wales Hospital by ambulance.
Approx. 0759 hrs (1559 LT)	Worker 3 was taken to the North District Hospital by ambulance.

Helicopter Electrical System Circuit Diagram



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Laboratory Test Report and Analysis by PolyU

Tests to Assess the Insulation Breakdown Strength of Air

Reasons for the Test

There was insulation breakdown which caused a flashover between the underslung Longline and the Overhead Line on 3rd January, 2011. In order to evaluate how close the underslung had moved to the proximity of the Overhead Line at the time of the incident, a simulation was carried out. In this simulation bare electrodes instead of conductors insulated by nylon jackets was used as a starting point. The reason for carrying out the insulation breakdown test using bare electrodes was to estimate the "longest" separation distance between two conductors to breakdown air at a given voltage. Once such distance was found, then the actual separation distance at the material time of the instant must be shorter than that between two bare conductors, because of the presence of insulators on the outside of the Longline. In other words, if two bare electrodes broke down at a separation distance of x for a given voltage, then the distance between the underslung and Overhead Line at the time of the incident must be smaller than x when the insulation broke down, because the insulation on the outside of the Longline should have a higher insulation breakdown strength than air.

Since the voltage at the Overhead Line was 132 kV between phases and $132/\sqrt{3}$ kV or 76.2 kV between any live phase and an earth conductor, the tests to be carried out should be of the same order of magnitude as the breakdown voltage at the time of incident. For breakdown voltages of around 76 kV and noting that the supply voltage of such magnitude could have variations up to +10% (i.e. it is possible for the transmission voltage to be 76.2 kV *1.1 or 83.8 kV), it is desirable that the test should be slightly higher than 84 kV and hence for the test to be conducted, it should preferably be designed to cover up to 84 kV. It is noted from Fig. 5 of IEEE Standard 516 – 2003 Issue that the breakdown strength of air is around 120 kV peak (or 84.9 kV rms) for a separation of 20 cm, hence the electrodes was designed to be spaced by around 21 cm, because if Fig. 5 of IEEE Standard 516 – 2003 Issue has anything to go by, then the breakdown voltage for a separation of 21 cm should be around 90 kV.

Even though it is shown in Fig. 3 of the IEEE Standard 516 that the breakdown strength is constant for voltages up to 700 kV (peak), it is desirable to double confirm the linearity of breakdown strength by halving the separation distance. If the breakdown voltage at a separation of 10.5 cm was about 50 % of that for a separation of 21 cm, then the linearity of breakdown strength was confirmed.

In order to ensure the environment was under control and the observation is repeatable, the Test Rig was housed inside a container so that external air movement would not have any undue effect on the test data. The container also allowed one to change the environmental condition in order to simulate conditions with 100% relative humidity as well as windy conditions with pollutants such as cement flying in the environment.

Moreover, it was necessary to check the effect on the shapes of electrodes upon the breakdown strength of air. Hence electrodes with sharp edges as well as round electrodes and flat electrodes were tested.

- **Test objective(s)**

To find out the longest separation distance between the Longline and the conductors at the material time of the incident if a flashover were to occur.

- **Test apparatus & its calibration**

A high voltage generator to generate the high voltage
A 1000:1 step down transformer for voltage measurement (ROSS, Model 061113-5-A; Serial No. VD90-8.3Y-A-LB-A-F) (internally calibrated with an accuracy of ± 3%)
A digital multi-meter (Flute Model 189, True RMS Multimeter; Serial No: 90730194) (with 0.025 % dc accuracy and 1 microvolt resolution), internally calibrated to ± 3%)
An oscilloscope to display the leakage current (Tektronix TDS380, 400 MHz)
Metal Ruler with a measurement uncertainty of ± 5%.

Overall the measured voltage should be accurate to ± 6% and the distance measurement should be accurate to ± 5%.

It is note that if the measured value is U (the measured voltage from Overhead Lines, for example) which is dependent on X (output of the step down transformer, for example) and Y (output from multi-meter to measure the output of the step down transformer, for example), therefore

$$U = X * Y$$

Taking small increment of both sides gives

$$\delta U = X * \delta Y + Y * \delta X$$

Dividing the above by U on left hand side and X*Y on right hand side gives

$$(\delta U / U) = (\delta X / X) + (\delta Y / Y)$$

Hence the total uncertainty when all factors are considered should be ± 3% ± 3%± 5% or ± 11% in total.

- **Test procedures / parameters**

Electrodes of different shapes was used in order to study whether sharp points on the electrodes would substantially affect insulating breakdown strength of air. The test procedures were:

Two electrodes were mounted on an insulating board with a separation of about 21 cm;
The set up was housed inside an essentially airtight plastic box;
A small opening was produced on the top of the plastic box to allow an airgun to blow air inside the box;
The voltage applied to the electrodes was increased from zero until breakdown occurred;
The applied voltage to the electrodes was reset to zero after breakdown occurred;
The container was then filled with water and the airgun was triggered and the voltage applied to the electrodes was increased from zero until breakdown occurred;
The applied voltage to the electrodes was reset to zero after breakdown occurred;
Cement was poured inside the box to emulate the environment with a lot of pollutant and the airgun was triggered to ensure there were lots of cement flying in air inside the plastic box;
The voltage applied to the electrodes was gradually increased from zero until breakdown occurred;
The applied voltage to the electrodes was reset to zero;
Water was poured into the box which was filled with cement;
The voltage applied to the electrodes was gradually increased from zero until breakdown occurred (note however the airgun was not triggered as there were concerns that a solid track could be established between the electrode and the airgun to pose an electric hazard to the operator);
The applied voltage to the electrodes was reset to zero;
The separation was changed to about 10.5 cm to confirm that the breakdown voltage was halved and the experiment was repeated all over again.
The tests were repeated with different shapes of electrodes to confirm the validity of the test results.

- **Test articles configurations and identification**

Electrodes which have smooth surfaces and sharp corners as well as a flat plate were used to evaluate the breakdown strength of air.

- **Condition of test(s)**

The test was carried out with normal ambient temperature and environment.

- **Test Results**

a) With Round Electrodes

Test Condition	Breakdown Voltage (kV)
Inside Container at normal environmental conditions	Between 90 to 102
Inside Container with Water and Airgun triggered to provide an environment with a Relative Humidity of 100 %	Between 90 to 102
Inside Container with Dry Cement and Airgun triggered to provide an environment with a lot of pollutant flying in air	Between 90 to 98
Inside Container with Cement and Water to provide an environment with a lot of pollutant in a rainy day (Airgun was however not triggered to minimize electric hazard)	Between 50 to 60 (however the breakdown was along the electrode supports rather than through air)

b) With Sharp Electrodes

Test Condition	Breakdown Voltage (kV)
Inside Container at normal environmental conditions	Between 87* to 102
Inside Container with Water and Airgun triggered to provide an environment with a relative humidity of 100 %	Between 87* to 102
Inside Container with Dry Cement and Airgun triggered to provide an environment with a lot of pollutant flying in air	Between 90* to 102
Inside Container with Cement and Water to provide an environment with a lot of pollutant in a rainy day (Airgun is however not triggered to minimize electric hazard)	Between 50 to 60 (however the breakdown was along the electrode supports rather than through air)

* It is noted that a voltage of 90 kV (with dry cement) instead of 87 kV (without dry cement) was required to breakdown the air when dry cement was poured onto the container but this does not imply the dry cement would make it more difficult for the air to breakdown. It only shows there could be variations in the breakdown strength of air when measured at different times and such variations are within normal engineering tolerances.

c) With One Sharp Electrode and one Plate Electrode

Test Condition	Breakdown Voltage (kV)
Inside Container at normal environmental conditions	Between 90 to 102
Inside Container with Water and Airgun triggered to provide an environment with a relative humidity of 100 %	Between 90 to 100
Inside Container with Dry Cement and Airgun triggered to provide an environment with a lot of pollutant flying in air	Between 90 to 95
Inside Container with Cement and Water to provide an environment with a lot of pollutant in a rainy day (Airgun is however not triggered to minimize electric hazard)	Between 50 to 60 (however the breakdown was along the electrode supports rather than through air)

It is noted that with the sharp electrodes, the magnitude of the flashover current was higher when compared with the test with round electrodes. However this is no substantial differences in the magnitude of the voltages required to breakdown the air due probably to measurement uncertainties which are common in practical engineering studies involving instrumentation.

Since the air typically broke down at an applied voltage of 90 kV for a separation of 21 cm when the tests were repeated several times, the breakdown voltage of 90 kV was taken as being representative of the test results (All the measured values are within 25% of the measurements at 90 kV).

When the separation distance was reduced from 21 cm to 10.5 cm, the voltages required to breakdown the air for both round and sharp electrodes were typically half of what were reported for a separation of 21 cm and hence all parties agreed on 26th October, 2011 the breakdown strength of air was linear for separation distances of the order of 10 cm to 20 cm.

- **Pass/Fail criteria and data collection**

There is no pass/fail in this test as the aim of the experiment is to find out the longest separation distance between two bare conductors to breakdown the air when the applied voltage was around 90 kV. The separation between the underslung Longline and the Overhead Line for breakdown to occur must however be shorter than that between two bare conductors since the insulation on the outside of the Longline will make flashover more difficult to appear.

To evaluate the cause of breakdown for a Small Circuit Breaker and Toggle Switch

- **Reasons for the Test**

A wealth of information have been given to the PolyU Team to assess the cause of a flashover incident on 3rd January, 2011. A small Circuit Breaker and a Toggle Switch together with three Avionic Equipments (e.g. ADF, Transponder and aircraft radio) on board of the incident Helicopter were found malfunctioning after the Incident. Since it was unlikely to have five devices malfunctioning at the same time due to intrinsic and natural defects, one would conclude that the failures were related to the incident, even though there is a very very slim chance of all five devices failing simultaneously and not attributed to the Incident. If one rules out the very slim chance of natural breakdown of all five devices at the same time, one would then conclude that the failure of the five devices/equipments were attributed to the Incident and, apart from sabotage, there are thus only two reasons for the failure to occur, one was due to electric effect and the other one was due to thermal effect.

With the facilities available at the University, it was fairly straightforward to simulate the presence of high voltage and evaluated how much surge current might flow into the devices. However there were insufficient facilities to simulate the presence of high temperature which might also render the devices to malfunction. On the other hand, one can use the logic of elimination in that if high voltage was not the culprit causing the failures, then it was the high temperature which caused the devices to fail.

If there were failures in equipments/instruments inside the cockpit of a Helicopter, then, apart from personal injury to the Workers at ground level as observed and reported for this incident, the failures could undermine the controllability of Helicopter to give rise to hazards which could adversely affect aviation safety and endanger human lives.

- **Test objective(s)**

As the flashover occurred near Overhead Lines of CLP Power, the flashover would likely to arise from high voltages which vary sinusoidally in time. However it is noted that the Longline might not be touching the overhead lines solidly as the Longline was probably swinging in air at the material time of the incident. In other words, the Longline might be "bouncing" onto the overhead line and hence the Longline might not be picking up a steady sinusoidal voltage from the Overhead Line. Instead of testing the devices with a sinusoidal supply, a more stringent test is to apply an impulse with a wavefront of 1.2/50 μs (i.e. the impulse rises to its peak in 1.2 μs and then falls to 50% of its peak in another 50 μs) to simulate the lightning surges that may appear at the material time of the flashover. This voltage would likely to cause more damages because of the high rate of change of voltage. If no damages are inflicted on the devices due to these surges at the end of the test, then sinusoidal voltages will be applied to double confirm whether the damages were due to high voltages.

- **Test apparatus & its calibration**

  a. A high voltage impulse generator to generate the high impulse voltage
  b. A standard single stage impulse generator from Haefely Test AG
  c. A 1000:1 step down transformer for voltage measurement (ROSS Engineering, Model 061113-5-A; Serial No. VD90-8.3Y-A-LB-A-F) (internally calibrated with an accuracy of ± 3%)
  d. A digital multi-meter (Fluke Model 189, True RMS Multimeter; Serial No: 90730194) (with 0.025 % dc accuracy and 1 microvolt resolution) (internally calibrated with an accuracy of ± 3%)
  e. An oscilloscope to display the leakage current (Tektronix TDS380, 400 MHz)
  f. A 200 Ω resistor with an accuracy of ± 3%.

The apparatus being used in the assessment was a standard single stage impulse generator from Haefely Test AG and information on their products can be obtained from www.haefely.com/10-products/10-impulse-voltage-testing. The wave shape of the impulse being applied was 1.2/50 μs which was a standard impulse defined in IEC 60-1. The waveforms were observed on a Tektronix Storage Digital Oscilloscope. In all the tests a breakdown implied a leakage current of more than 5 mA. After a current of more than 5 mA had flown (which implied there was a breakdown in the electric properties of the devices being tested, and once broken down, the device would breakdown again at a much lower voltage compared to when the device was first tested)

It is note that if the measured value is U (the measured voltage from Overhead Lines, for example) which is dependent on X (output of the step down transformer, for example) and Y (output from multi-meter which measures the output from the step down transformer, for example), therefore

$$U = X * Y$$

Taking small increment of both sides gives

$$\delta U = X * \delta Y + Y * \delta X$$

Dividing the above by U on left hand side and X*Y on right hand side gives

$$(\delta U / U) = (\delta X / X) + (\delta Y / Y)$$

Hence the total uncertainty when all factors are considered should be ± 3% ± 3% or ± 6% in total.

- **Test articles configurations and identification**

The following setup were being used to carry out the Impulse Test on the Longline.

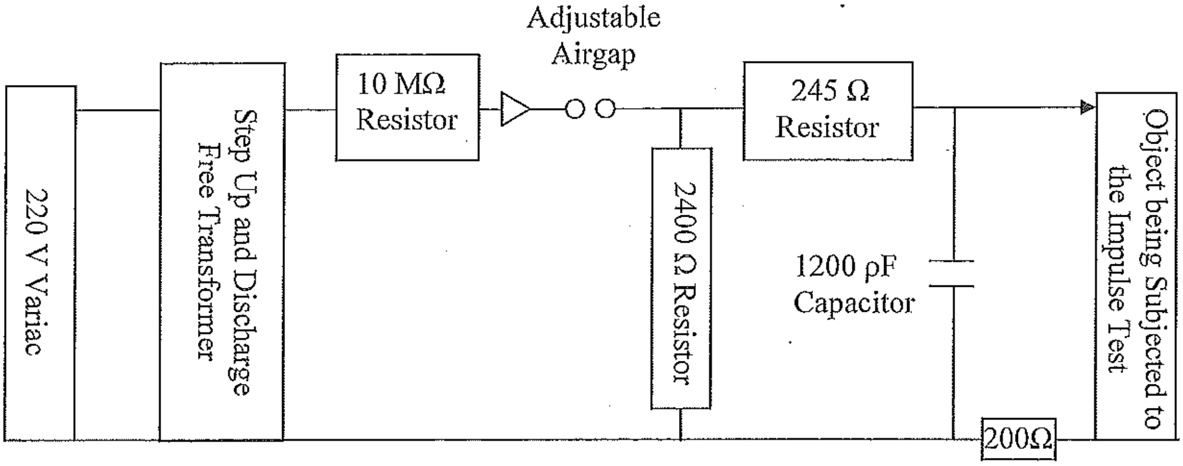

Fig. D1 Circuit Arrangement for the Impulse Test

- **Test procedures / parameters**

The first issue to look into was whether electric current had indeed entered the Helicopter. In theory, transient electric current could creep along the electric cable, which was embedded in the Longline, to enter into the electric circuits inside the Helicopter. However such transient current might not be large enough to cause real damage. Hence the following test was carried out to find out to what extent the electric current had gone into the Helicopter:

1. ***Test on the Toggle Switch***
   a. Set the Toggle Switch to the Open position;

   b. Impulse voltages up to 100 kV were applied to one side of the Toggle Switch and the corresponding current flowing into the Toggle Switch was measured by measuring the voltage drop across a 200 Ω resistor;
   c. The resistance across the terminals for both open and close positions were measured after each test voltage to evaluate the status of the device.

   The test was repeated with the Toggle Switch in the Close Position.

- **Test Results**

Apply Voltage (kV)	Current Flowing into the Toggle Switch
100	Not detectable

After the application of 100 pulses, the resistance across the Toggle Switch in the close position was 0.2 Ω and that for the open position was infinity when measured with a multimeter. This indicated that the Toggle Switch was not damaged by the high surges.

2. *Test on the Circuit Breaker*

a. The Circuit Breaker was checked to ensure it was in the normal position (which was the closed position) with an "ON" resistance of less than 1 Ω;

b. Impulse voltages up to 100 kV were applied to one side of the Circuit Breaker and the corresponding current flowing into the Toggle Switch was measured by measuring the voltage drop across a 200 Ω resistor;

c. The resistance across the Circuit Breaker was measured after the application of test voltage to evaluate the status of the device.

- **Test Results**

Apply Voltage (kV)	Current Flowing into the Circuit Breaker
100	Not detectable

After the application of 100 pulses, the resistance across the Circuit Breaker was 0.2 Ω when measured with a multimeter.

- *Pass/Fail criteria and data collection*

As both devices survived after the test with no functional failure (For the Toggle Switch, it has a resistance higher than 100 MΩ between the open-circuited terminals measured with a multimeter and less than 1 Ω on short-circuit measured with a multimeter; The Circuit Breaker has a normally "ON" resistance of less than 1 Ω measured with a multimeter), then sinusoidal voltages up to 100 kV was also applied to both the Toggle Switch and the Circuit Breaker using the following circuit configuration.

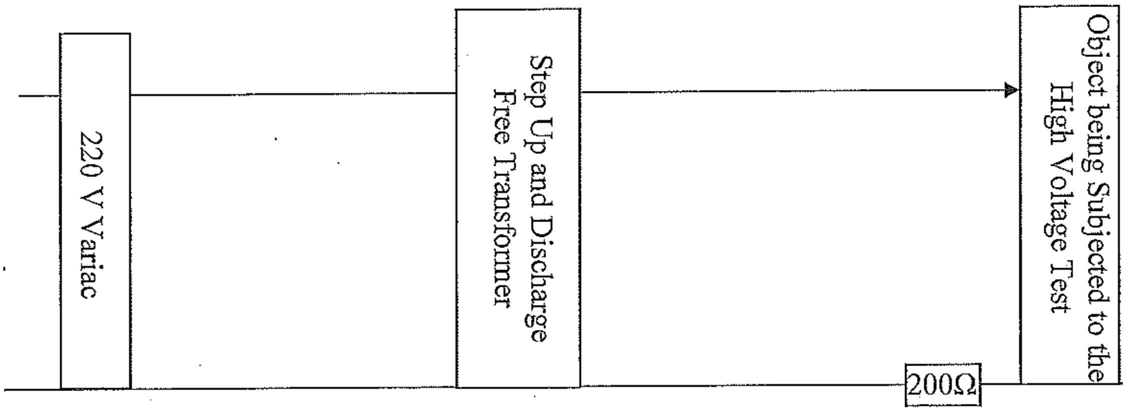

Fig. D2 Setup to generate sinusoidal high voltage

- **Test Results**

a) For the Toggle Switch

Apply Voltage (kV)	Current Flowing into the Toggle Switch
100	Not detectable

After application of 100 kV for 2 minutes, the resistance across the Toggle Switch in the close position was 0.2 Ω and that for the open position was infinity when measured with a multimeter.

b) For the Circuit Breaker

Apply Voltage (kV)	Current Flowing into the Circuit Breaker
100	Not detectable

The resistance across the Circuit Breaker was 0.2 Ω when measured with a multimeter.

After application of 100 kV for 2 minutes, neither the Toggle Switch nor the Circuit Breaker failed according to the passing criteria as that stipulated for the impulse test (i.e. no current higher than 5 mA flowed into the device), one could confirm that insufficient electric charges have gone into the failed device(s) to cause a failure.

As both devices failed after the incident on 3rd January, 2011, then based on the method of elimination, one can conclude that the failures were due to the high temperature which was transmitted along the copper wire of the electric cable embedded inside the Longline.

On the other hand, no tests had been carried out on the three Avionic devices (ADF, Transponder and aircraft radios), they could either be damaged by the small electric charges conducted along the embedded low voltage cable or by the high temperature conducted by the copper conductor of the low voltage cable. In the absence of the embedded low voltage cable, none of the five devices would however fail if the Longline was dry, unless a big fire occurred along the Longline and into the cockpit of the Helicopter.

To evaluate the insulation breakdown strength of the Longline with and without embedded electric cable

Reasons for the Test

There was electrical breakdown on the surface of the Longline and part of the low voltage cable embedded in the Longline was blown away. It was therefore necessary to find out how much voltage was needed to cause the insulation on the Longline to fail.

Before finding the insulation breakdown strength of the Longline in its totality, it would be interesting to find out the insulation breakdown strength of the low voltage cable, as it is clear that the low voltage cable had broken down electrically even when it was protected by the outside sheath of the Longline at the material time of the incident.

In order to assess how close the Longline had moved to the vicinity of the overhead line, one needs to find how much voltage was required to breakdown the insulation in the extreme case when the electrodes were touching the Longline. In essence. if a voltage of *x* kV was needed to breakdown the insulation of the sheath, then as the voltage at the time of the incident was 76.2 kV and assumed the breakdown strength of air was y kV per cm, then the Longline had probably come to a distance of the order of [(76.2 – x) / y] /2 cm (assuming the Longline was equally separated from the Overhead Lines and the Stay Wire which was earthed).

It would also be useful to find out the insulation breakdown strength of the dry and clean Longline in the absence of embedded low voltage cable. If the insulation strength of the dry and clean Longline was substantially higher than 132 kV per 3 m of length (assuming the separation between the two phases of the Overhead Line was 3 m as given in Reference *I*), then it might even be possible for the Longline to touch two phases of the Overhead Line (whose voltage difference is 132 kV) with no immediate danger of insulation breakdown. If there were no immediate danger for the Overhead Line to touch any two phases in the Overhead line, then it would also be safe for the Longline to touch one Overhead Line and the Stay Wire (assuming the physical separation between one phase and the Stay Wire stayed at 3 m) because the voltage difference between the Overhead Line and the Stay Wire is only 76.2 kV for a 132 kV system. However the distance between the Overhead Conductor and the Stay Wire might not necessarily be 3 m and there could also be other conditions which affect the insulation property of the Longline, thus due care had to be exercised when drawing guidelines on the minimum air insulation distance.

After the aforementioned tests, the Longline was soaked in tap water and the insulation strength of it was assessed again to check if it would be safe to allow a soaking wet Longline to come to the close proximity of the Overhead Line. As the insulation strength of the Longline was found to become very low once wet at the University, one should regard the Longline as a "conductor" and sufficient air clearance must be provided to avoid flashover from the Overhead Line to the Longline.

Despite of all the tests being carried out on both dry and wet Longline, it would however be recommended that there should be a safe distance between the Overhead Line and the Longline in order to ensure the highest degree of safety.

- **Test apparatus & its calibration**

a. A high voltage step-up transformer was used to generate the high voltage
b. A 1000:1 step down transformer for voltage measurement (ROSS Engineering, Model 061113-5-A; Serial No. VD90-8.3Y-A-LB-A-F) (internally calibrated with an accuracy of ± 3%)
c. A digital multi-meter (Fluke Model 189, True RMS Multimeter; Serial No: 90730194) (with 0.025 % dc accuracy and 1 microvolt resolution) (internally calibrated with an accuracy of ± 3%)
d. An oscilloscope to display the leakage current (Tektronix TDS380, 400 MHz)
e. A 200 Ω resistor with an accuracy of ± 3%.

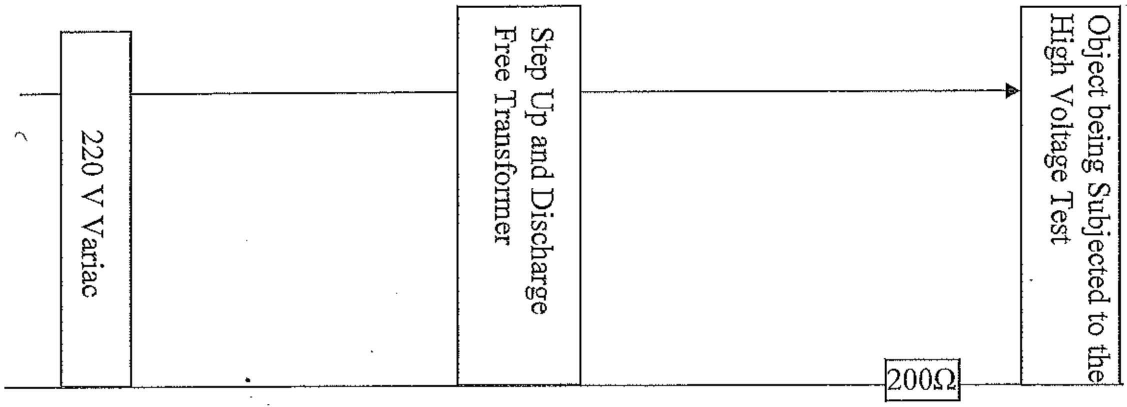

Fig. F1 Setup to generate sinusoidal high voltage

- **Test on the Low Voltage Cable**

In order to evaluate how much voltage was needed to breakdown the electric cable, a short length of the electric cable of about 10 cm was cut off and a voltage was applied gradually to find out at what voltage would the insulation of the low voltage cable fail. The equipment being used was a high voltage generator from Haefely Test AG and the methodology of the test was

a. A small tin foil was wrapped on the outside of the electric cable to ensure the contact was solid and the test result was repeatable.

b. The ends of the conductors were properly terminated by putting all loose conductors into cable terminations.
c. A voltage from the setup as shown in Fig. F1 was applied between the tin foil on the outside of the cable and one of the three conductors in steps of 1 kV until breakdown occurred.

- **Test Results**

Apply Voltage (kV)	Current Flowing into the Device
3*	More than 5 milli-amperes and the supply was tripped

* An initial voltage of about 500 V was present from the setup which was designed to give an output up to 100 kV. No current was detected at 500 V. However it was difficult to increase the output voltage from the setup very slowly in steps of 1 kVand a slight adjustment resulted in an output voltage of 3 kV

- **Pass/Fail criteria and data collection for the Low Voltage Cable**

There is no pass/fail criteria and the test is to find out the insulation breakdown level of the low voltage cable embedded inside the underslung Longline. It was confirmed experimentally that the low voltage cable could withstand a voltage of around 3 kV.

- **Tests on the Longline**

To verify whether the polyethylene Longline would fail in the inadvertent event of it getting very close into the vicinity (i.e. with a distance much shorter than 0.2 m or even in the order of mm) of live conductors, the following test was carried out:

Fig. F2 The Longline being assessed

a. The low voltage electric cable was moved away from the main body of the Longline.
b. Tin foils were wrapped on location B with the separation between locations A and B being 0.5 m and A was connected to the low voltage side of the high voltage source.
c. The voltage was increased between A and B slowly in steps of around 10 kV until breakdown occurred.

- **Test Results**

Apply Voltage (kV)	Current Flowing between Points A and B
10	0.15 mA
20	0.4 mA
30	0.92 mA
40	2.15 mA (Sheath of Longline was on fire)

As the applied voltage was being increased, the input current into the Longline increased in a non-linear manner. Nonetheless the current did not increase beyond 5 mA even though the sheath of the Longline was on fire when a voltage of 40 kV was applied. This characteristics inferred that the Longline was behaving like a slightly non-linear resistor whose resistance was governed by the formula of $\rho l/a$ (where ρ is the resisitivity of the material which in this case is mainly polyethylene and nylon, l is the length and a is the cross-sectional area). The polyethylene rope appeared to have been burnt after the small fire (as mentioned in the table above) was put off as shown in Fig. F3. It is also worth noting that the fire broke out at a location at which the electrical resistance was high (probably due to inhomogeneous electrical properties of the rope because of bending, for example).

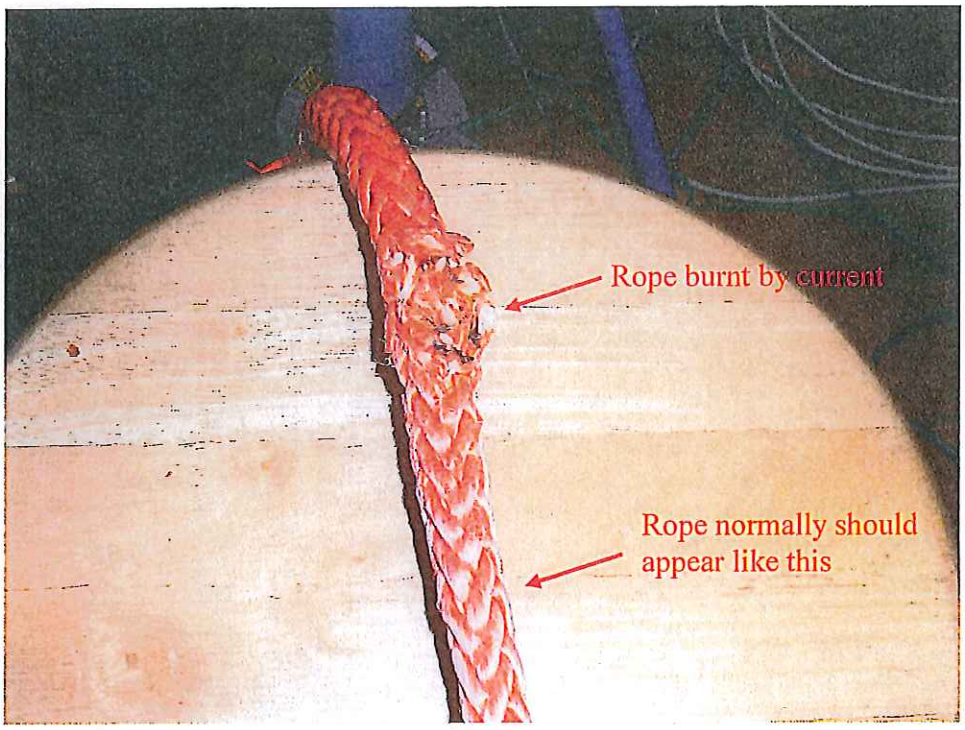

Fig. F3 The polyethylene rope was burnt when the sheath was broken down electrically with an application of 40 kV

As there was no sudden sharp increase in the input current input the Longline which implied that the Longline was essentially behaving as a resistor, one can conclude that the input current to the Longline was generally dependent on the length of the Longline, even though certain voltage was required to overcome the insulation of the sheath. Consequently one can predict that the longer the Longline, the higher will be the insulation resistance of the Longline. In other words, the input current to the Longline was still largely governed by the relationship of $I = (V - V_s)/ R$, where V_s is the voltage required to breakdown the outside jacket of the Longline, R is the resistance of the polyethylene rope which is proportional to the length through which current flowed.

In order to identify how the presence of electric cable weakened the insulation properties of the Longline, the electric cable was put back and a high voltage was applied gradually as follows:

a. A section of the Longline which had no history of electric breakdown was chosen.

b. The low voltage electric cable was put back to its normal embedded location of the Longline.
c. Tin foils were wrapped on locations C and D with the separation between locations C and D being 0.5 m. D was connected to the low voltage side of the high voltage source.
d. The voltage between C and D was increased slowly in steps of 5 kV until breakdown occurred.

- **Test Results**

Apply Voltage (kV)	Current Flowing between Points A and B
5	0.04 mA
10	0.08 mA
15	0.16 mA
20	0.27 mA
25	0.4 mA
30	0.55 mA
35	0.73 mA
40	0.95 mA
45	1.14 mA and then increased sharply beyond 5 mA

It is noted in this test, the applied voltage has to breakdown the insulation of the jacket of the Longline covering the embedded cable at entry (at which high voltage was applied), the insulation of the low voltage cable at entry (at which high voltage was applied), the insulation of the low voltage cable at exit (at which the high voltage was returned to the source) and the insulation of the sheath at exit (at which the high voltage was returned to the source). Hence the resistance of the Longline with embedded cable for this test is different from the case when there was no embedded cable in the Longline.

As the applied voltage was increased beyond 45 kV, the current suddenly increased sharply beyond 5 mA and the power supply to the Test Rig was tripped. This indicated the insulation of the sheath as well as the insulation of the low voltage cable were broken down at that time. A large current then flowed into the Longline when the applied voltage to the Longline was maintained. In other words, with the presence of low voltage cable inside the Longline, the breakdown would be rather "sudden" as the applied voltage did not need to overcome the insulation of the copper conductor meter by meter (copper is an excellent conductor and hence if the insulation covering the copper conductor broke down, the current, which is governed by $I = (V - V_s)/ R$ will become very large as the resistance R of copper is very small).

To evaluate the case when one end of the low voltage cable was connected to the Secondary Hook which was somehow making contact with an earthed object, one further experiment was carried out. For that experiment the low voltage cable was put back into the Longline and tin foil was wrapped onto point B (Fig. E2) and one of the copper conductors of the low voltage cable was earthed. High voltage was applied to one of the cores of the low voltage cable.

- **Test Results**

Apply Voltage (kV)	Current Flowing between Points A and B
5	0.6 mA
10	2 mA for a short while and then it increased sharply to trip out the power supply

This test again demonstrated the weakest link in terms of insulation was the low voltage cable. Once the insulation of the sheath and cable insulation broke down, the current increased very drastically.

In order to evaluate the impact of rain on the insulation properties of the Longline, the Longline was immersed in a buckle of tap water for 5 minutes and then the Longline was hung in air for another 5 minutes. The following tests were then carried out:

a. A section of the Longline which had no clear history of electric breakdown was chosen.

b. The low voltage cable was taken out from the main body of the Longline.
c. Tin foils were wrapped on locations A and B with the separation between locations A and B (which were different A and B locations mentioned earlier since this was a new test) being 0.5 m. A was connected to the low voltage side of the high voltage source.

d. The voltage between A and B was increased slowly until breakdown occurred.

- **Test Results**

Apply Voltage (kV)	Current Flowing between Points A and B
0.1	The current increased to more than 5 mA to trip out the power supply to the Test Rig

It was observed that once wet, the Longline behaved like a reasonable conductor and hence it would be very dangerous for the Longline to come to the proximity of high voltage Overhead Lines.

- **Pass/Fail criteria and data collection**

There is no pass/fail criteria as the proposed tests are to evaluate the insulation breakdown strength of the Longline. It should be noted however that once there were insulation breakdown, then there would be permanent damages in the Longline and a much lower voltage was needed to cause a relatively large current to flow. For example, in the absence of insulation breakdown, an applied voltage of 10 kV might circulate micro-amperes into the Longline. After the breakdown, a voltage of just 1 to 2 kV might circulate tens of milli-amperes into the Longline. In other words, there would be a very marked difference in the ratio of applied voltage to input current with or without breakdown.

In summary, all the tests being proposed in this section are to evaluate how close was the Longline to the Overhead Line at the material time of the flashover and whether it is necessary to disallow the fitting of electric cables along the main body of the Longline.