SMOKE CAME OUT OF THE DADO PANEL IN REAR CABIN DURING PASSENGERS DISEMBARKING

EVA AIRWAYS FLIGHT BR67
BOEING 747-400, B-16410
BANGKOK SUVARNABHUMI INTERNATIONAL AIRPORT FEBRUARY 23, 2008

Final Report

AVIATION SAFETY COUNCIL

TAIWAN, THE REPUBLIC OF CHINA

Report Number: ASC-AFR-09-05-002

Report Date: February 25, 2011

Executive Summary

On February 23, 2008, EVA Airways (EVA) BR67, a Boeing 747-400, Republic of China (ROC) registration B-16410, was a regularly scheduled flight from Taoyuan International Airport, Taiwan, ROC to Bangkok Suvarnabhumi International Airport, Thailand. There were 2 pilots, 3 additional cockpit crewmembers, 14 cabin crewmembers, and 296 passengers on board the flight.

At 0934, the aircraft took off from Taoyuan International airport and landed at Bangkok International airport at 1301. The aircraft parked at the gate and started the disembarkation at about 1307. At about 1310, rear cabin passengers discovered smoke coming from the left DADO Panel under seats 64A/65A. The cabin crew directed passengers to leave the aircraft through the aerobridge immediately. After passengers left the aircraft, the EVA Bangkok maintenance representative turned off the electrical power, discharged an onboard fire extinguisher in the cabin toward the source of the smoke through the meshed DADO Panel and put out the smoke. All people onboard were safe. Cabin door L4 and R5 were opened by passengers during the disembarkation.

The EVA Bangkok maintenance representative accessed to the waste tank compartment in the aft cargo section and found the rivets in attaching the aluminum standoff for wiring were broken and fell off. One of the 3 phase APU power supply cables of No. 1 APU generator chafed against the attached bolt of waste tank tube fixture that resulted in a chaffing damage of the cable. It was presumed that from the chaffing, the exposed cable then grounded with the aircraft structure, caused the short circuit, and the subsequent cabin smoke. The maintenance representative examined the surrounded area, found no abnormality for aircraft systems other than the generator cables and fire damaged insulation blankets. Soot on the nearby surfaces could be removed the soot by hand, according to his report. According to the findings, the representative deactivated the APU and repaired the defective APU power cable with insulation wrappings before the aircraft was released for the scheduled flight to the next destination, London.

The occurrence notification to the council was received on February 25 and the aircraft returned to Taiwan on February 26. The council recognized that the event met the definition of “aviation occurrence” according to Article 2 of the

Aviation Occurrence Investigation Act, ROC. As a result of this occurrence happened outside of the territory of ROC, the council immediately contacted Thailand's Department of Civil Aviation (DCA) in accordance with Article 6 of the Act. The DCA, Thailand delegated the whole part of the investigation to the council in compliance with Section 5.1, Chapter 5 of ICAO Annex 13.

Findings related to probable causes

1. The excessive load resulted from improper routing and installation of the APU cables, together with the complicate stress condition during aircraft's dynamic motion, had contributed to the overload and breakage of the STA 2060 standoff. (2.1.3)

2. The insulation jacket of the detached APU power cable, which had fallen with the failed standoff, then contacted and started chaffing with a tip of a fastener where the cable had landed. Finally the insulation of APU power cable was worn with abrasion which caused the arcing and the fallen sparks ignited the contamination substance on the insulation blankets below. (2.2)

3. A weaker material selection of nylon was not the root cause for the failure of the standoff, the subsequent arcing and the fire. The Service letter 747-SL-24-060 issued on 7th August 2001, proposing an Aluminum standoff in replacing the Nylon ones, is deemed insufficient in resolving the standoff breakage problem. It is concluded that the excessive loading from improper routing and installation of the APU cables and the complicate stress condition during aircraft's dynamic motion operation had both contributed to the breakage of the standoff, which were the vital causes of the occurrence. (2.1.3)

Findings related to risk

1. According to FAA's test report, a cotton swab burning test was done on two samples without visible contamination. The fires were all extinguished within 8 inches which satisfied the requirement. The same burning cotton swabs were dropped on two contaminated blankets, and the fires extended beyond permitted 8 inches. The more contaminations on the blanket the larger the area of fire would be. (1.16.2)

2. According to Chap. 1.6.7.2, contamination of insulation blankets, Chap. 1.12.2.1, under floor structure, and Chap. 1.16.2 FAA test results on insulation

blankets, the contaminations included CIC etc. CIC on the cover film of insulation blanket is capable of collecting animal hairs, lint and cotton fibers than the blanket without CIC contamination. The accumulation of contamination will result in more serious fire. (2.2.1)

3. The period from the date of the last D Check to the date of accident is 3 years and 6 months (3.5 years). The fire of the accumulated contaminations already resulted in substantial damage to airplane structure. There still have 2 years and 6 months (2.5 years) to the next D Check. The contamination on insulation blankets will be more serious. FAA's test report revealed that the more contaminations the larger the areas of fire will be and the more serious damage to airplane will be. Currently, the D Check interval of EVA's 747 airplane is 6 years. The 2.5 years' time interval from the last time D Check was finished to the next D Check will result in serious fire once the insulation blanket is caught fire. (2.3.1)

4. EVA could not take it seriously to incorporate the maintenance actions of CIC contaminated insulation blanket in accordance with AMM into job card 1A62IN. Maintenance personnel will have no actions at all once they encounter similar condition. (2.3.2)

5. EVA did not pay proper attention on the evaluation of the received service letter 747-SL-25-170-B to avoid the accident. It is revealed that EVA did not take seriously considerations the effects of CIC and cotton contamination on insulation blankets. The present maintenance programs need to be improved. (2.3.3)

6. From the inspection result in the home base, the floor beam was confirmed damaged from the fire at BKK, it revealed that the succeeding revenue flights from BKK to LON then back to CKS after the fire did not have a complete dispatch procedures safety regulations. (2.3.4)

7. Because there were no any tools and related training to assist cabin crew discovering the fire source in cargo, compartment the cabin crew of this flight could not immediately identify the fire source. (2.5.1)

8. Because cabin crew could not discover the fire source, the fire fighting procedures were not executed. (2.5.2)

9. The smoke spread rapidly within E zone after the occurrence. Due to the class divider curtains were not opened, the smoke couldn't propagate evenly and

passenger and cabin crew wasn't able to see the entire cabin. Crew did not use public announcement to inform E zone the abnormal situation and to instruct the forward passenger to speed up the disembarkation. Cabin crew did not use proper wording to calm down the passengers and give self protection instructions. Under the above conditions, some panic passengers pushed the cabin crew, operated the exit door without cabin crew's permission. (2.5.4)

10. The cabin crew didn't to secure their exit door or re-assign acting crews prior to leave their duty zone to assist other crew member so that the L4 door was not secured by any cabin crew and was opened. (2.5.5)

Other findings

1. The thickness measurement results of the straight part and ear part of the standoff are corresponding with the requirement. The material of the sample meets the required 6061-T6 aluminum alloy specification due to the results of the microstructure inspection and micro-hardness tests. (1.16.1)

2. There are fatigue striations characteristics in fracture surface, and ductile dimple-fracture region are found, and the region is supposed to be the final overload fracture. Base on the above analysis, conclusions of CSIST are made as follows: *The cable bracket (standoff) was failed due to fatigue loading effect. It is concluded that the upper ear of the bracket was fracture by excessive fatigue load at the corner, and which subsequently caused the deformation of the lower ear and the loosening of the rivet.* (2.1.1)

3. The standoff carried an extra downward loading of 18 pounds. (1.12.2.1)

4. Contaminations on the insulation blankets included CIC, fibers, animal hairs, mineral particles, Styrofoam, metal fragments and insects, etc. CIC contamination on insulation blankets should be due to the application of CIC on structure accidentally during the time maintenance personnel doing structural inspection. Artificial fibers should be from interior furnish such as cloth cover of chair or carpet, and clothes of passengers and crew members. Mineral particles and insects should be from the circulation of air condition system. Animal hairs, Styrofoam and metal fragments should be left from passengers or other personnel. （2.2.1）

5. The conclusion of the Boeing test report and the component analysis of the insulation blanket surface thin film stated that the insulation blanket cloth was

in accordance with the requirement. (1.16.2)

6. Number 1 APU circuit had current difference larger than the setting of 20±5 amps and exceeded more than 0.04 seconds. Circuit protection was activated to trigger AGCR and power breaker APB which interrupted power supply of number 1 APU. The trip of APU power supply prevented power cable from arcing and subsequent fire risk. The function of number 1 AGCU to protect APU generators and power supply was normal during the occurrence. (2.4)

7. No relevant abnormality was input in the maintenance records. (1.6.8.4)

8. The notification from cabin crew to purser and captain of this flight was compliant with the procedures of cabin crew handbook. (2.5.1)

9. EVA Air's cabin crew fire fighting training program is completely compliant with CAA's requisition. (2.5.2)

10. The occurrence happened during the disembarkation phase with the aircraft already parked in place. Launching the evacuation procedures might en-danger the passengers due to their panic reactions and rushing to the exit doors with limited time to notice the ground vehicles to leave, in addition, the evacuation might need more time compared to rapid disembarkation from the bridge. (2.5.3)

Recommendations

To EVA Air

1. Assessment of the fleet wide condition of the APU power cable installation at BS2060 standoff, including inspection, measurement, and correction of the pre-existing excessive loading if found.

2. In an effort to take account of Boeing's experience and service letter 747-SL-25-170-B, enhancing the evaluation of contamination in the cargo compartment to revise maintenance plan of cabin and cargo compartment accordingly.

3. Review and evaluate job card number 1A62IN and related job cards in accordance with AMM to add inspective and corrective procedures such that maintenance personnel can be complied with.

4. It was not a complete dispatch release to fly from Bangkok to London, Bangkok and Taoyuan. Eva should enhance the outside station maintenance

release discipline to eliminate any similar flight to be released for service.

5. To enhance the flight and cabin crew's procedures regarding the fire source identification, fire fighting operation, the timing of using curtain, re-assigning acting crews prior to their leaving their duty zones, leadership, communication, announcement and passenger comforting, especially in the aisle occupied situation. The improved procedures should be put into their related training courses.

To CAA

1. Supervise the operator to assure the mitigation means against the pre-existing excessive loads by assessment/correcting actions of the fleet wide APU power cable installation at BS2060 standoff.

2. Supervise EVA's efforts on the evaluation of contamination in the cargo compartment to revise maintenance plan of cabin and cargo compartment.

3. Supervise EVA's efforts on the evaluation of job card number 1A62IN and related job cards to add inspective and corrective procedures such that maintenance personnel can be complied with.

4. Supervise the operator to ascertain the maintenance discipline and skill level at the out stations will be able to eliminate any substandard and similar flights to be released for service.

5. Supervise the operator to enhance the flight and cabin crew's procedures regarding the fire source identification, fire fighting operation, the timing of using curtain, re-assigning acting crews prior to their leaving their duty zones, leadership, communication, announcement and passenger comforting, especially in the aisle occupied situation. The improved procedures should be put into their related training courses.

To Boeing

1. Develop a solution to eliminate the failure of the STA 2060 standoff which the excessive load had exerted, contributed from the improper routing and installation of the APU cables and the complicate stress condition during aircraft's dynamic motion, had resulted in the breakage of the STA 2060 standoff.

To FAA

1. Supervise the manufacturer to implement a solution to eliminate the failure of the STA 2060 APU power cable standoff which the excessive load resulted from improper routing and installation of the APU cables, together with the complicate stress condition during aircraft's dynamic motion, had contributed to the overload and breakage of the STA 2060 standoff.

Content

Tables

Figures

1 Factual Information

1.1 History of Flight

On February 23, 2008, EVA Airways (EVA) BR67, a Boeing 747-400, Republic of China (ROC) registration B-16410, was a regularly scheduled flight from Taoyuan International Airport, Taiwan, ROC to Bangkok Suvarnabhumi International Airport, Thailand. There were 2 pilots, 3 additional cockpit crewmembers, 14 cabin crewmembers, and 296 passengers on board the flight.

At 0934[1], the aircraft took off from Taoyuan International airport and landed at Bangkok International airport at 1301. The aircraft parked at the gate and started the disembarkation at about 1307. At about 1310, rear cabin passengers discovered smoke coming from the left DADO Panel under seats 64A/65A. The cabin crew directed passengers to leave the aircraft through the aerobridge immediately. After passengers left the aircraft, the EVA Bangkok maintenance representative turned off the electrical power, discharged an onboard fire extinguisher in the cabin toward the source of the smoke through the meshed DADO Panel and put out the smoke. All people onboard were safe. Cabin door L4 and R5 were opened by passengers during the disembarkation.

The EVA Bangkok maintenance representative accessed to the waste tank compartment in the aft cargo section and found the rivets in attaching the aluminum standoff for wiring were broken and fell off. One of the 3 phase APU power supply cables of No. 1 APU generator chafed against the attached bolt of waste tank tube fixture that resulted in a chaffing damage of the cable. It was presumed that from the chaffing, the exposed cable then grounded with the aircraft structure, caused the short circuit, and the subsequent cabin smoke. The maintenance representative examined the surrounded area, found no abnormality for aircraft systems other than the generator cables and fire damaged insulation blankets. Soot on the nearby surfaces could be removed the soot by hand, according to his report. According to the findings, the representative deactivated the APU and repaired the defective APU power cable with insulation wrappings before the aircraft was released for the scheduled flight to the next destination, London.

[1] All times contained in this report is Taipei local time (UTC plus 8), unless otherwise noted.

The occurrence notification to the council was received on February 25 and the aircraft returned to Taiwan on February 26. The council recognized that the event met the definition of “aviation occurrence” according to Article 2 of the Aviation Occurrence Investigation Act, ROC. As a result of this occurrence happened outside of the territory of ROC, the council immediately contacted Thailand's Department of Civil Aviation (DCA) in accordance with Article 6 of the Act. The DCA, Thailand delegated the whole part of the investigation to the council in compliance with Section 5.1, Chapter 5 of ICAO Annex 13.

1.2 Injuries to Persons

No one sustained injury.

1.3 Damage to Aircraft

One floor beam and two stringers of the aircraft primary structure were partially suffered from elevated heat condition. A non-destructive inspection confirmed that the affected aircraft structure was substantially damaged from heat. Generator cables and wiring also required repair. See 1.12 for detail.

1.4 Other Damage

Not applicable.

1.5 Personnel Information

1.5.1 Pilots

Table 1.5-1 Basic Information of Pilots

Item	CM-1	CM-2
Gender	Male	Male
Age as of accident	43	33
Date of joining in EVA	December 1, 1997	October 20, 2004
License type	Airline Transport Pilot	Airline Transport Pilot
Type rating Expire date	B747-400 May 17, 2010	B747-400 F/O June 1, 2012
Medical class Expire date	1st class airman April 30, 2008	1st class airman June 30, 2008
Latest flight check	November 28, 2007	November 10, 2007
Total flight time	15,362 hrs 45min.	4,632 hrs 4 min.
B747-400 flight time	3,165 hrs 45 min.	2,556 hrs 57 min.
Flight time in last 12 months	618 hrs 20 min.	950 hrs 42 min.

Flight time in last 90 days	122 hrs 09 min.	243hrs 16 min.
Flight time in last 30 days	20 hrs 13 min.	67 hrs 24 min.
Flight time in last 7 days	13 hrs 20 min.	13 hrs 47 min.
Flight time on the day of accident	3 hrs 49 min.	3 hrs 49 min.
Rest time period before accident	13 hrs 50 min.	11 hrs 57 min.

1.6 Aircraft Information

1.6.1 Aircraft Basic Information

The basic information of the aircraft refers to Table 1.6-1.

Table 1.6-1 Aircraft Basic Information

Aircraft Basic Information (Data Accumulated up to Feb. 23, 2008)	
Nationality	Republic of China
Aircraft Registration Number	B-16410
Type of Aircraft	B747-45E
Manufacturer	Boeing Company, USA
Manufacturer's Serial Number	29061
Date Manufactured	January 19, 1998
Date Delivered	January 19, 1998
Owner	EVA Airways
Operator	EVA Airways
Certificate of Airworthiness, Number/Validity Period	97-01-018/January 15, 2009
Total Flight Hours	49,232:02
Total Cycles	7003
Type and Date of Latest Periodic Inspection	A04 Check February. 19, 20088
Flight Hours/Cycles Elapsed Since Last Maintenance Check	39:54 Flight Hours/8 Cycles
Date of Latest D Check	November 11, 2002
Date of Transition D Check	August 24, 2004
Maximum Operational Takeoff Weight	394,625/317,513 kgs

1.6.2 Engine Basic Information

The aircraft installed four CF6-80C2B1F engines which were manufactured by the GE (General Electric) Company. The related basic information of the engines is shown in Table 1.6-2.

Table 1.6-2 Engine Basic Information

Engine Basic Information (Data Accumulated up to Feb. 23, 2008)				
Manufacturer	General Electric Company			
Number/ Location	No. 1/Left	No. 2/Left	No. 3/Right	No. 4/Right
Type	CF6-80C2B1F	CF6-80C2B1F	CF6-80C2B1F	CF6-80C2B1F
Serial Number	704104	704334	702800	706476
Total Hours	63,396 hrs	56,516 hrs	46,558 hrs	28,364 hrs

1.6.3 Weight and Balance

The maximum takeoff weight of this aircraft was 317,513 kg, and the maximum landing weight was 285,763 kg. The maximum zero fuel weight of this aircraft was 242,671 kg. The center of gravity index range of takeoff and landing were limited between 10.1% M.A.C. and 31.5% M.A.C. The center of gravity index range of takeoff and landing for zero fuel weight were limited between 15.0% M.A.C. and 31.6% M.A.C.

According to the load sheet of the aircraft, the weight and balance information is as follows:

Table 1.6-3 BR67 weight and balance information

Zero fuel weight	222,000Kg
Take off fuel	41,900Kg
Takeoff weight	263,900Kg
Estimate trip fuel	30,200Kg
Estimate landing weight	233,700Kg
Take off C.G.	23.9% M.A.C.

1.6.4 Auxiliary Power Unit Power Supply System

During normal flight operation, the aircraft's electrical power is supplied by four main generators which are driven by engines. Before takeoff or after landing and taxing on the ground, the aircraft's electrical power may be supplied from the APU generators or from ground power source. The auxiliary power unit power supply system includes two APU generators, generator manual reset panel, five converters, two APU power breakers, two bus control units and two auxiliary generator control units (AGCU). The AGCU is used to monitor the input current, voltage and frequency if stable. If there were any abnormality existed, the AGCU will be tripped to ensure the safety of APU power supply system.

1.6.4.1 APU Generator

There are two exchangeable APU generators of the same type. Each generator is connected to a quick releasable ring of a gear box which is located on the tail section of aircraft. The generator is a 400Hz, three phases, 115 volts, brushless and magneto type with maximal capacity of 90 kilo watts

1.6.4.2 APU Generator Wires

According to page 5.1, chapter 24-21-51 of Boeing 747 Wiring Diagram Manual (WDM), one APU generator may power three wires which are labeled W944-111-2/0(AL), W944-112-2/0(AL) and W944-113-2/0(AL). The designation of W944-111-2/0(AL), for example, is that W944 stands for wire bundle number, 111 stands for wire number, 2/0 stands for gauge number "00" with diameter 0.3648 inch if American Wire Gauge (AWG) were adopted, and AL stands for aluminum material.

The wire bundle starts from APU chamber using AWG number "0" copper wire to connect each generator. After passing through the fire wall of APU chamber, each wire bundle then connects with AWG number "00" aluminum wire and passes through cabin floor from left and right routes. The wire bundles fix in structure using plastic or aluminum standoff (refer to Fig 1.6-1). Finally, the wire bundles connect to the auxiliary Power Breaker (APB) on the P714 and P715 panels of Main Equipment Center (MEC) (refer to Fig. 1.6-2).

Fig. 1.6-1 Fixture of APU Generator Wires

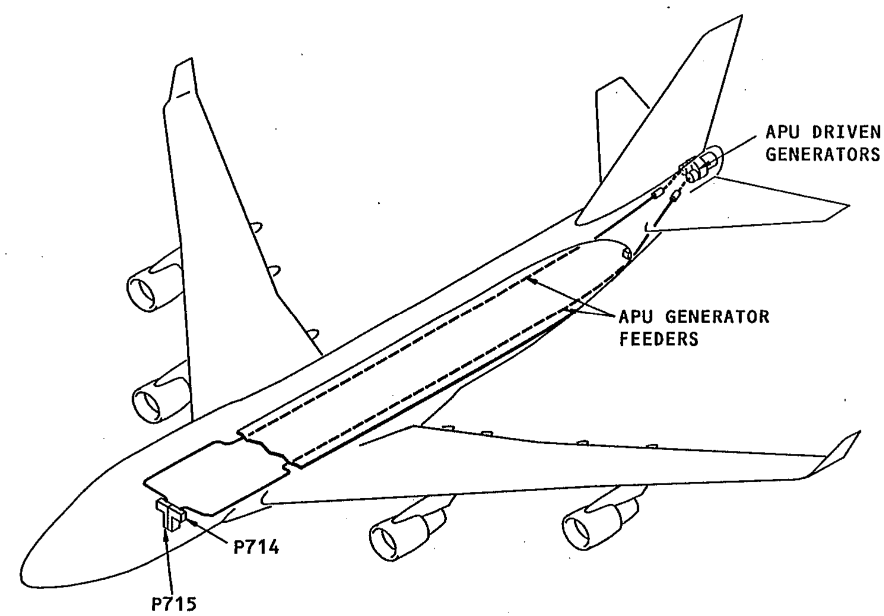


Fig. 1.6-2 APU Generator System

1.6.4.3 APU Generator Control

The switch of APU generator control is located on the aircraft electrical control panel which is designed on upper deck cockpit (refer to Fig. 1.6-3).

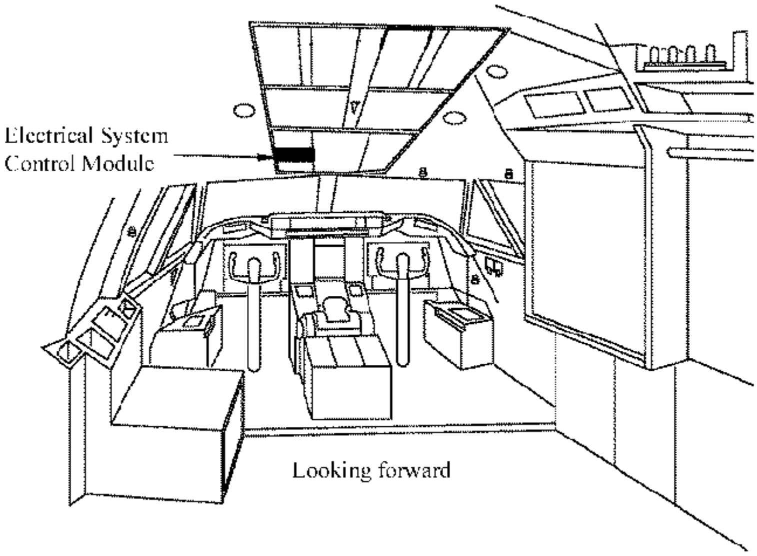


Fig. 1.6-3 Position of Electrical System Control Panels

The function and position of each switch are briefly stated as follows.

1. APU generator switch 1, 2: When the white AVAIL light on, generators output voltages and frequencies are within stable range. Pressing the switch can turn on or turn off the power from APU generator to the electrical system.

2. APU generator switch power light on: When APU generator provides electrical power to related electrical system, the white light is on.

3. Generator Control (GEN CONT): When the generator power (engine driven) is available, pressing the switch will connect the generator power to related electrical system.

4. Generator Control light ON: Represent the generator power is in available status and is providing power to related electrical system.

5. Generator Control light OFF: Represent the generator power is not in available status and is not providing power to related electrical system.

Fig. 1.6-4 Positions of APU Generator Control Switches

1.6.4.4 Power Supply Sequence of APU Generator

The time to use APU generator power is after aircraft landing and entering apron, before parking and connecting ground power, or after aircraft removing ground power and push back, before leaving apron. To transit the power from engine driven main generator to APU generator power, starting APU first. When the RPM of APU N1 reaches 95%, APU GEN 1, 2 switches which located at P5 panel AVAIL light are ON. After pilot pressing number 1 or 2 AVAIL switch, main generator and number 1 or 2 APU generator are running concurrently. When APU generators output voltages and frequencies are within stable range, main generator GCB is tripped and APU generators take over power supply. If number 1 or 2 APU AVAIL light is not on, and generator control light OFF, APB P714 or P715 is opened with no power available.

1.6.4.5 Mechanism of APU Generator Protection

Two identical AGCU take charge of power control and protection of APU generators. When APU generator is supplying power, AGCU can protect electrical system when the following unusual conditions existed:

1. Overvoltage (OV): When the voltage exceeds 130±3 volts, APU generator will trip power supply.

2. Undervoltage (UV): When the average of three phase voltage lower than 104.5±1.5 volts and exceed 9±1 seconds, APU generator will trip power supply.

3. Underspeed (US): When the RPM lower than 95%, after 0.25-0.60 delay

time APU generator will trip power supply.

4. Differential Current: The Differential Current Protection monitors current difference between circuit and generator. When differential current larger than 20±5 amps and exceed 0.04 seconds, the current protection will activate APU generator control relay and power breaker to trip generator power supply.

Table 1.6-4 Function of AGCU Power Protection

FUNCTION	SENSING	THRESHOLD	TIME DELAY	TRIPS	REMARKS
OVERVOLTAGE (OV)	HIGHEST PHASE POR VOLTAGE	>130 ±3 VOLTS	INVERSE	AGCR, APB	
UNDERVOLTAGE (UV)	AVERAGE OF 3-PHASE POR VOLTAGES	<104.5 ±1.5 VOLTS	9 ±1 SEC	AGCR, APB	LOCKED OUT BY US
UNDERSPEED (US)	APU UNDERSPEED SWITCH	APU SPEED LESS THAN 95% <380 Hz	0.25 TO 0.60 SECONDS	APB	LOCKS OUT UV
DIFFERENTIAL CURRENT PROTECTION (DP)	GENERATOR DPCT AND LINE DPCT	20 ±5 AMPS ABSOLUTE DIFFERENCE BETWEEN GENERATOR CURRENT AND SUM OF LOAD AND SYNC BUS CURRENT	0.04 SECONDS	AGCR, APB	
POWER READY	NONE	OV, UV, US, OC	150 ±50 MSEC		APB WILL CLOSE IF NO TRIPS ARE PRESENT

1.6.5 APU Standoff

APU power supply cables are fixed by using Boeing BACN10TL3-18 standoff. The material of this standoff is 6061-T6 aluminum alloy. This standoff was installed on airframe structure by two rivets and the other side using a spacer and a self locking nut to secure cables to prevent the cable from chafing with structure or other equipments (refer to Fig. 1.6-1).

1.6.6 Insulation Blanket

According to Boeing Material Specification (BMS), the insulation blanket of aircraft furnishings should be made of light weight, fire resistant and flexible material. The main purposes of insulation blanket are heat insulation and noise reduction. The interior of insulation blanket stuffs with fiber glass and covered with fire resistant reinforced plastic cover film. Because of the restrictions of aircraft interior shape and system equipments, the size of insulation blankets installed in each locations are not all the same. Basically, 20 inches are set as one unit in aircraft to install insulation blankets. The installation closely attached to aircraft skin to match each frame and stringer of aircraft structure. Each insulation blanket in different locations with different size has different parts number.

Upon inspecting the insulation blankets been burned and replaced around the area of aft cargo compartment and waste tank compartment, some recognizable information on the cover film include Boeing parts number, referred date of blue print and manufacturer. The referred dates of blue print (refer to Table 1.14-1) are all earlier than the delivery date (Jan. 19, 1998) of the accident aircraft.

According to EVA Air 747 type AMM 25-00-00-308-038 (Oct. 18, 2007), all the insulation materials in Boeing 747 aircraft with delivering date earlier than Sep. 2, 2003 that does not conform to US Federal Aviation Regulations (FAR) part 25.856[2], should change the cover film of insulation blanket to BMS8-142 or BMS8-115 type materials on next repair. The delivering date of the accident aircraft was Jan 19, 1998. The insulation blankets installed on the area around aft cargo compartment and waste tank compartment conform to the specifications specified in FAR part 25.856.

1.6.7 Air Conditioning System

1.6.7.1 Introduction to Air Conditioning System

The air conditioning system includes air cycle machine (ACM), conditioned air distribution and recirculation, temperature control and heating subsystems to provide a comfortable environment for passengers, crew and cargo systems. Air sources for the air conditioning packs are generated from engine, APU or ground air supply. Conditioned air enters the overhead distribution ducts and then connecting to sidewall diffusers. A flow divider in the sidewall diffuser duct provides proper air through the passenger compartments. Air flow circulation diagram is shown in Fig. 1.6-5. Passenger compartment air leaves the cabin through return air grilles in the sidewall at floor level to lower cargo compartments. Two recirculation fans under the main deck floor provide the recycled air to distribution ducts and mixed with fresh air. Two outflow valves

---

[2] (a) The thermal/acoustic insulation material installed in the fuselage is required to meet the flame propagation test requirements of part VI of Appendix F to Part 25, or other approved equivalent test requirements

(b) Aircrafts with a passenger capacity of 20 or greater, thermal/acoustic insulation materials installed in the lower half of the aircraft fuselage is required to meet the flame penetration resistance test requirements of part VII of appendix F of Part 25, or other approved equivalent test requirements. This requirement does not apply to thermal/acoustic insulation installations that the FAA finds would not contribute to fire penetration resistance.

locate lower aft cargo compartment discharge part of the recycled air to control the pressure attitude of cabin.

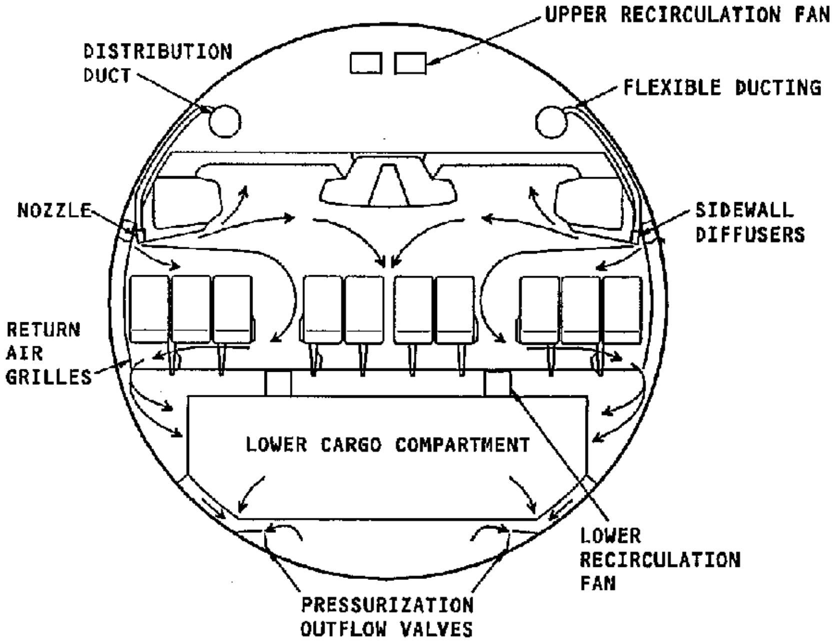


Fig. 1.6-5 Air Circulation of Cabin and Cargo Compartment

1.6.7.2 Contamination of Insulation Blanket

After the accident, the insulation blankets at left side passenger compartment and lower cargo compartment, from station 2020 to station 2060, were all replaced. The insulation blankets from station 2000 to station 2020 were also cleaned during the replacement of burned blankets. ASC investigators boarded the aircraft and took blanket samples from station 1940 to station 2000 at lower aft cargo compartment (refer to Fig. 1.6-6~Fig. 1.6-8). The locally magnified photos a1, b1 and c1 in each figure were all located below the return air grills. Those photos showed more accumulation of animal hair, synthetic fiber and cotton fiber than those of other locations of blanket. A corrosion inhibiting spray compound (CIC) that is used to protect aluminum structure was visible as a contamination in the area. The CIC and other contaminates on the cover film of insulation blankets turned the blanket faces darker, as shown in figure 1.6-8. The examinations found less accumulation of animal hairs, fibers and lint on the blanket areas that did not have CIC contamination.

Fig. 1.6-6 Sample of Insulation Blanket (1)

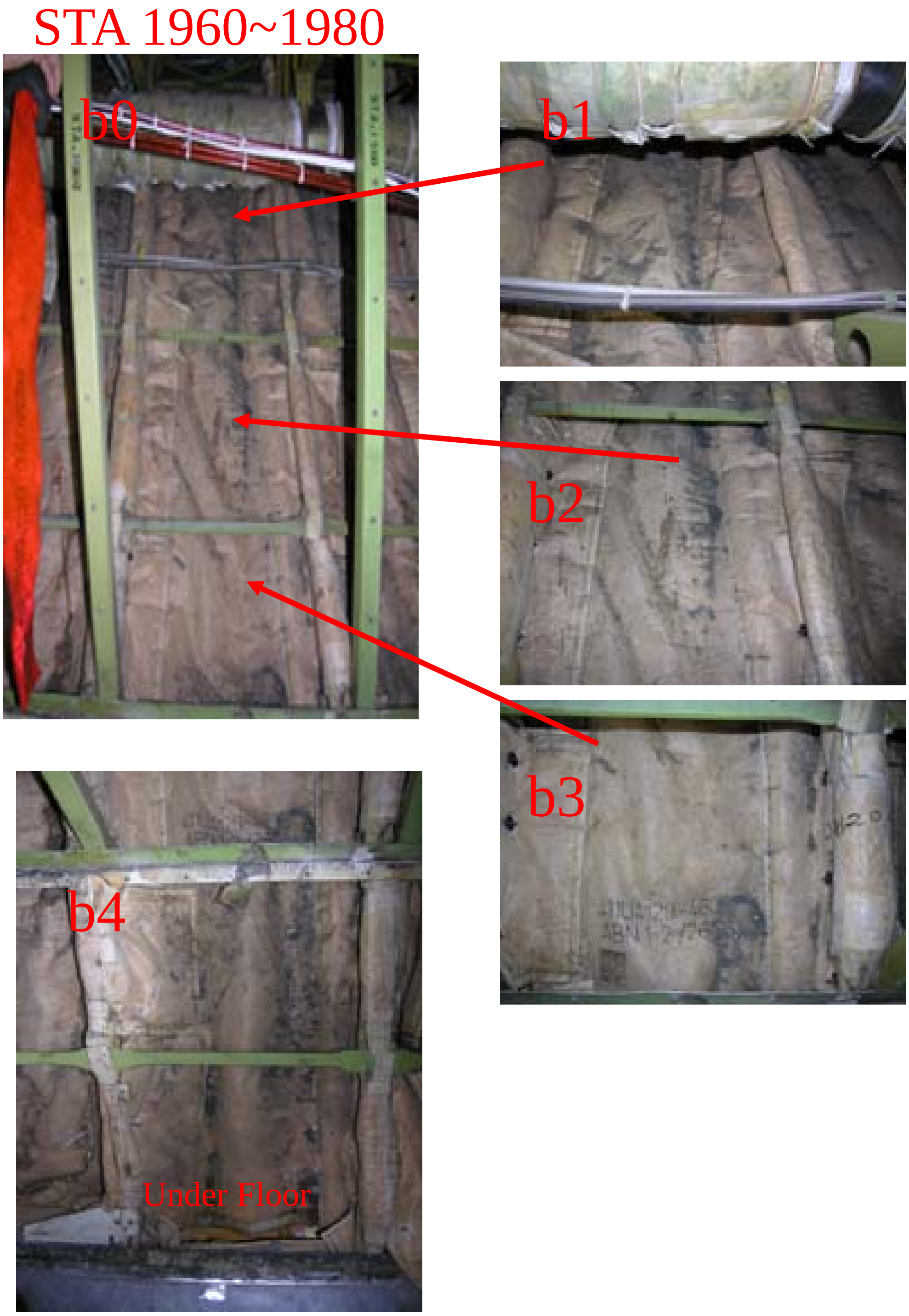


Fig. 1.6-7 Sample of Insulation Blanket (2)

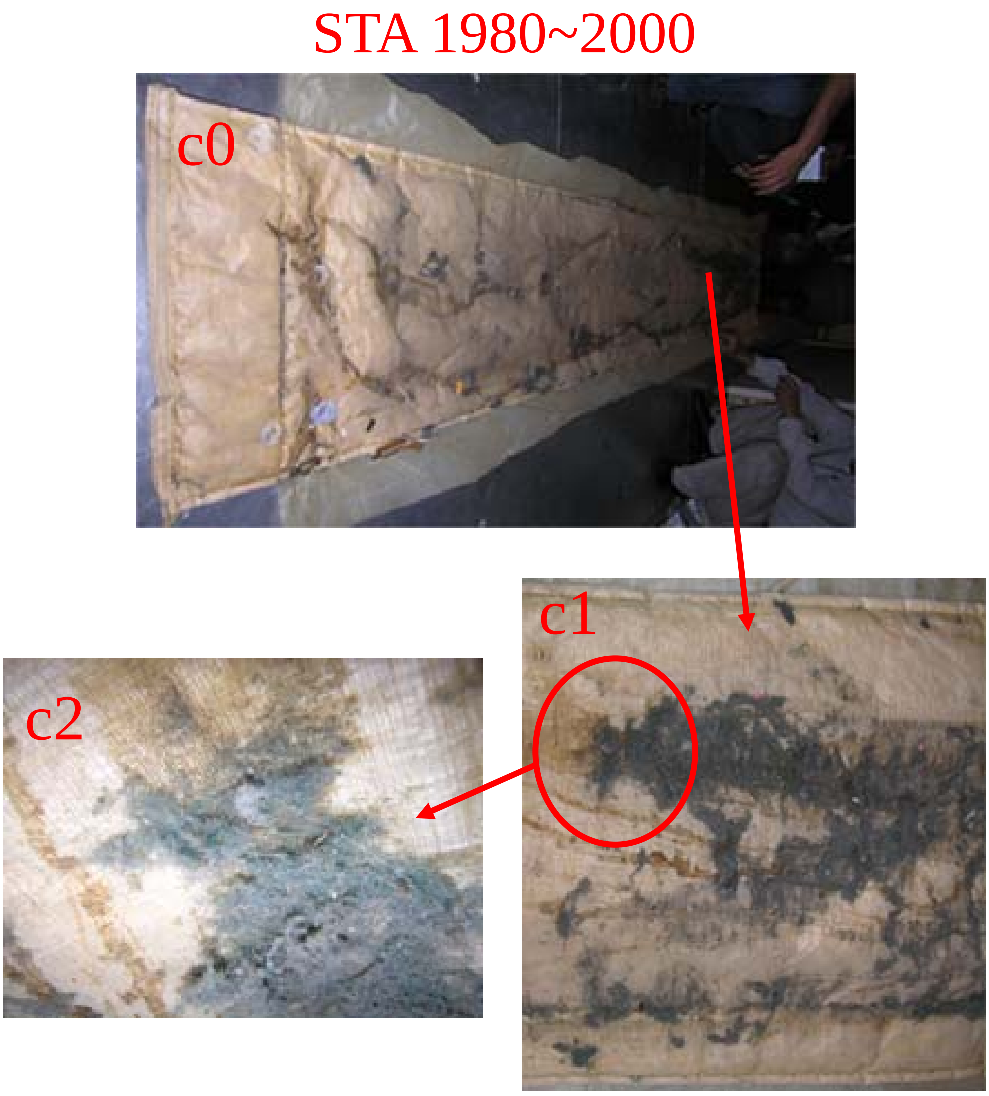


Fig. 1.6-8 Sample of Insulation Blanket (3)

1.6.8 Maintenance Related Documents

1.6.8.1 Boeing Service Letter

Boeing issued a multi-model service letter with the subject: "PREVENTING CONTAMINATION THAT AFFECTS FLAMMABILITY OF INSULATION BLANKETS" on March 23, 1998. This service letter was issued for all aircraft manufactured by Boeing. The service letter number of 747 type aircraft is 747-SL-25-170. The main subject of this service letter was to inform operators the potential fire hazard from the arcing of a wire bundle which might result in a fire on Corrosion Inhibiting Compound (CIC) contaminated insulation blankets. The suggested operator action of this service letter is listed as below.

Operators are advised to increase attention to periodic inspection and cleaning of the aircraft during maintenance to avoid blanket contamination, and remove foreign materials.

Boeing revised and reissued the service letter as numbers 747-SL-25-170-A and –B (see Appendix 1) on June 6, 2004 and August 6, 2004. Added contents included suggested cleaning information and other model aircraft.

The cleaning information to suggested operator action is listed as below.

1. *Blankets with observable fluids or oily/waxy substances (which typically change the color and appearance of the cover film) should be removed and replaced with new blankets.*

2. *Use low lint paper products and floor mats to clean debris from passenger's shoes as they enter the aircraft may help to control amounts of contamination brought into the aircraft.*

3. *Increase the frequency of vacuuming carpet and upholstery to reduce the volume of dirt and fibers in the cabin.*

The dates EVA received these three service letters, 747-SL-25-170, 747-SL-25-170-A and 747-SL-25-170-B, were on April 10, 1998, July 26, 2004 and August 30, 2004 respectively. About the treatment of the insulation blankets contaminated with CIC, EVA replied their actions and policy on September 18, 2009:

EVA quoted the incorporation of the note from AMM: 「NOTE: Do not apply water displacing/anti-corrosion compounds in the following areas: cables, pulleys, wiring, plastics, elastomers, oxygen systems adjacent to tears or holes in insulation blankets interior materials, including cargo liners. APU, APU shroud or any structure in direct contact with the lubricated or Teflon surfaces (e.g. greased joints, sealed bearings) .」 into Para. 7 Note (b) of Job Card 「1A62IN」and Para. G (1) Note of Job Card 「1A43IN」 which prohibited the contamination of CIC on insulation blankets.

1.6.8.2 Aircraft Maintenance Manual

In reference to AMM 25-55-03-404-009, date of revision October 18, 2007, the related statement about CIC contamination and insulation blankets is listed as below:

If there is Corrosion-inhibiting Compounds (CIC) contamination, oily or waxy substances or other fluids (which typically changes the color and appearance of the insulation blanket cover), replace the insulation blanket.

According to Boeing's reply, the date of revision of the above statement was May 2006.

1.6.8.3 Job Card 1A62IN

Upon checking Job Card number 1A62IN, item 2 of page 1, dated Aug. 24, 2004, the job asked using vacuum air or dry rag or wiper to clean contamination on insulation blanket. The original text is listed as follows.

2. *Use vacuum air or dry rag (or wiper) to remove accumulation of dust, lint, or trash (general litter) from insulation blanket and aircraft structure.*

In page number 2, the note of item 7 asked some restrictions on certain parts during the application of CIC on aircraft structure. The original text is listed as follows.

Note: Do not apply water displacing/anti-corrosion compounds in the following areas:

(a) Cables, pulleys, wiring, plastics, elastomers, oxygen systems.

(b) Adjacent to tears or holes in insulation blankets.

(c) Interior materials, including cargo liners.

(d) APU, APU shroud or any structure in direct contact with the APU.

(e) Lubricated or Teflon surfaces (e.g. greased joints, sealed bearings).

(f) Over cosmoline 1058 or equivalent per MIL-C-16173 grade 1.

(g) Areas with electrical arc potential.

(h) Engine strut cavities or cowling structure.

(i) Regions where temperature exceeds 220 degrees Fahrenheit (100 degrees Centigrade).

The recent work of job card 1A62IN on EVA 747 fleet (aircraft registration number B-16412) was finished on June 18, 2009. ASC investigator found that this job card was revised on Apr. 23, 2009. The above mentioned item 2 of page 1 was deleted from job card 1A62IN and the note 「CLEAN DUST OR COTTON FIBER BEFORE INSPECTION.」 was added in the cover page.

1.6.8.4 Maintenance Record

From the maintenance records before the date of accident, the aircraft finished an A04 check on Feb. 19, 2008 and no abnormality was found. The downloaded records from Central Maintenance Computer (CMC) were also checked. An APU GENERATOR/FEEDER-1FAIL message (refer to Fig. 1.6-9) was found before the date of accident with flight number BR68 from Bangkok to Taipei. After the aircraft arriving Taiwan, the number 1 APU was checked by maintenance personnel and the result was normal.

CMC History Retrive Report

A/C No	FLT No	RPT_DATE	CMC	EICAS	ATA	S ATA	PHASE	Fail Mod	A	CONTENT
B16410	EVA391	01/08 01:27		24500400	24	50				F/O XFR BUS S
B16410	EVA391	01/08 01:27	24059		24	51	PO			F/O TRANSFER RELAY FAIL (BCU)
B16410	EVA391	01/08 00:36		24500100	24	50				CAPT XFR BUS S
B16410	EVA391	01/08 00:36	24060		24	51	PF			CAPT TRANSFER RELAY FAIL (BCU)
B16410	EVA391	01/08 07:05	24138		24	22	PO			AIR/GND SWITCH FAIL (BCU-2)
B16410	EVA391	01/08 07:05	24124		24	22	PO			AIR/GND SWITCH FAIL (BCU-1)
B16410	EVA391	01/07 10:33	24099		24	34	LT			APU BATTERY CHARGER FAIL (BCU-2)
B16410	EVA391	01/07 10:33	24177		24	41	LT			BCU-2 HOT BATTERY SENSE INPUT FAIL
B16410	EVA68	01/23 22:17	24046		24	41	TA	H	A	EXT POWER SOURCE-2 FAIL INTERLOCK OVERCURRENT (BCU-2)
B16410	EVA68	01/23 22:17	24023		24	41	TA	H	A	EXT POWER SOURCE-1 FAIL INTERLOCK OVERCURRENT (BCU-1)
B16410	EVA68	02/22 10:20	24049		24	21	LT	H	A	APU GENERATOR/FEEDER-1 FAIL (BCU-1)
B16410	EVA67	02/23 19:41	24163		24	22	LT	I		UTILITY POWER-2 OFF (BCU)
B16410	EVA67	02/23 19:47	24059		24	51	TA	I		F/O TRANSFER RELAY FAIL (BCU)

Fig. 1.6-9 CMC Download Records

1.7 Meteorological Information

Not applicable.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

Not applicable.

1.10 Airport Information

Not applicable.

1.11 Flight Recorder

1.11.1 Cockpit Voice Recorder

The aircraft was equipped with a Solid-State Flight Data Recorder (SSCVR), manufactured by L3 Communication Inc., part number S100-0080-000, serial number 000278897, with 30 minutes recording capability. Because the BR67 flight continued its' flight duty to London, UK, the total recording didn't cover the occurrence period due to the recording capability of SSCVR.

1.11.2 Flight Data Recorder

The aircraft was equipped with a Solid-State Flight Data Recorder (SSFDR), manufactured by Honeywell, part number 980-4700-033, serial number 4814. The total recording of 52 hours, 49 minutes and 26 seconds of data was downloaded successfully.

The recorded data was readout according to the readout document provided by EVA Air[3.] The 32 mandatory recoded parameters were complied with the Aircraft Flight Operation Regulations Appendix 7, published by Taiwan CAA. The SSFDR readout information is summarized as follows:

1. The SSFDR was started recording at UTC 0919:58 at Taoyuan International Airport, and stopped recording at UTC 1305:47 at Bangkok International airport.
2. At UTC 0934:01the BR67 took off from RWY05 at Taoyuan International Airport. At UTC 1301:29 the BR67 landed at RWY01 at Bangkok International airport.
3. Before the SSFDR stopped recording at Bangkok International Airport, there were no fire, smoke, and event warning related events to be found according to the SSFDR recording parameters[4].

1.12 Wreckage and Impact Information

The upside surface of the insulation blankets (area measured 20 inches by 70 inches each) between STA 2020 and STA 2060, stringer S-26L to S-38L, were burnt in various extend. The bottom surface of the main deck composite floor

---

[3] The readout document is 747 DFDAC Interface Control Document.

[4] The fire, smoke, and event warning related parameters for this SSFDR include：AFT Cargo Fire, APU fire, Fire MN Deck (AFT, FWD, MID, >2ZN),Equip Bay Smoke, Event Record, Lav Smoke, Master Warning, D5 Crew Rest Smoke, Wheel Well Fire.

panel was partially carbonized and delaminated with heat damage (area measured 16 inches by 24 inches). One cabin side wall panel lower edge was found damaged by heat. For aircraft structure, one ventilation truss, one floor beam web for an affected area of 7 inches by 7 inches, and two stringers were found discolored with smoke; the residual strength of the structure were confirmed that had been compromised by heat with non-destruction test (NDT). The APU power cable standoff was found broken and felt off from the attachment; insulation jacket of the APU power cable charcoaled and melt locally; and the metal core of the cable was also melt; on the tip of a bolt belonging to the waste system was found melt with high temperature. All damage sites were summarized in Fig. 1.12-1 and Fig. 1.12-2.

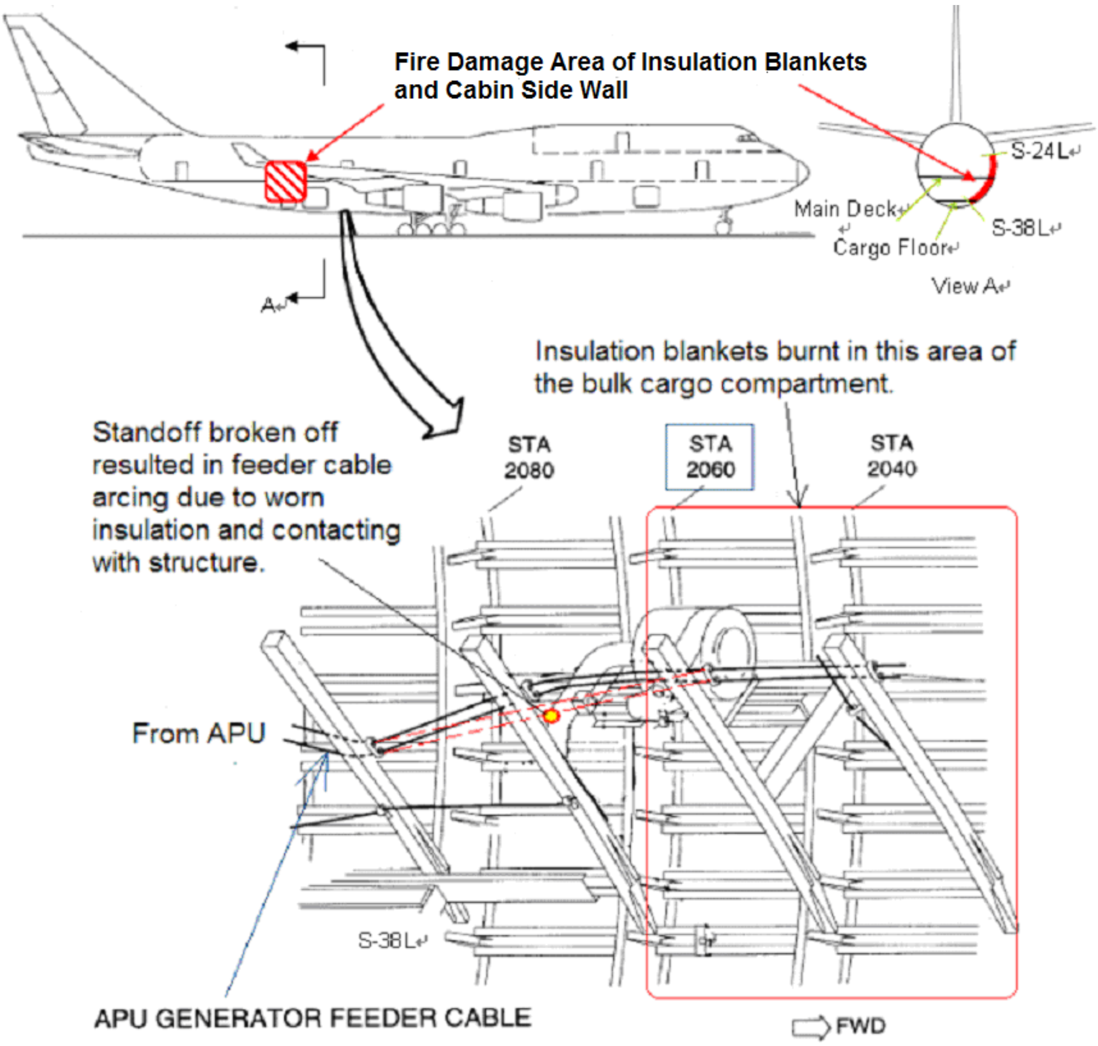


Fig. 1.12-1 Location of the Damaged Insulation and APU Power Cable

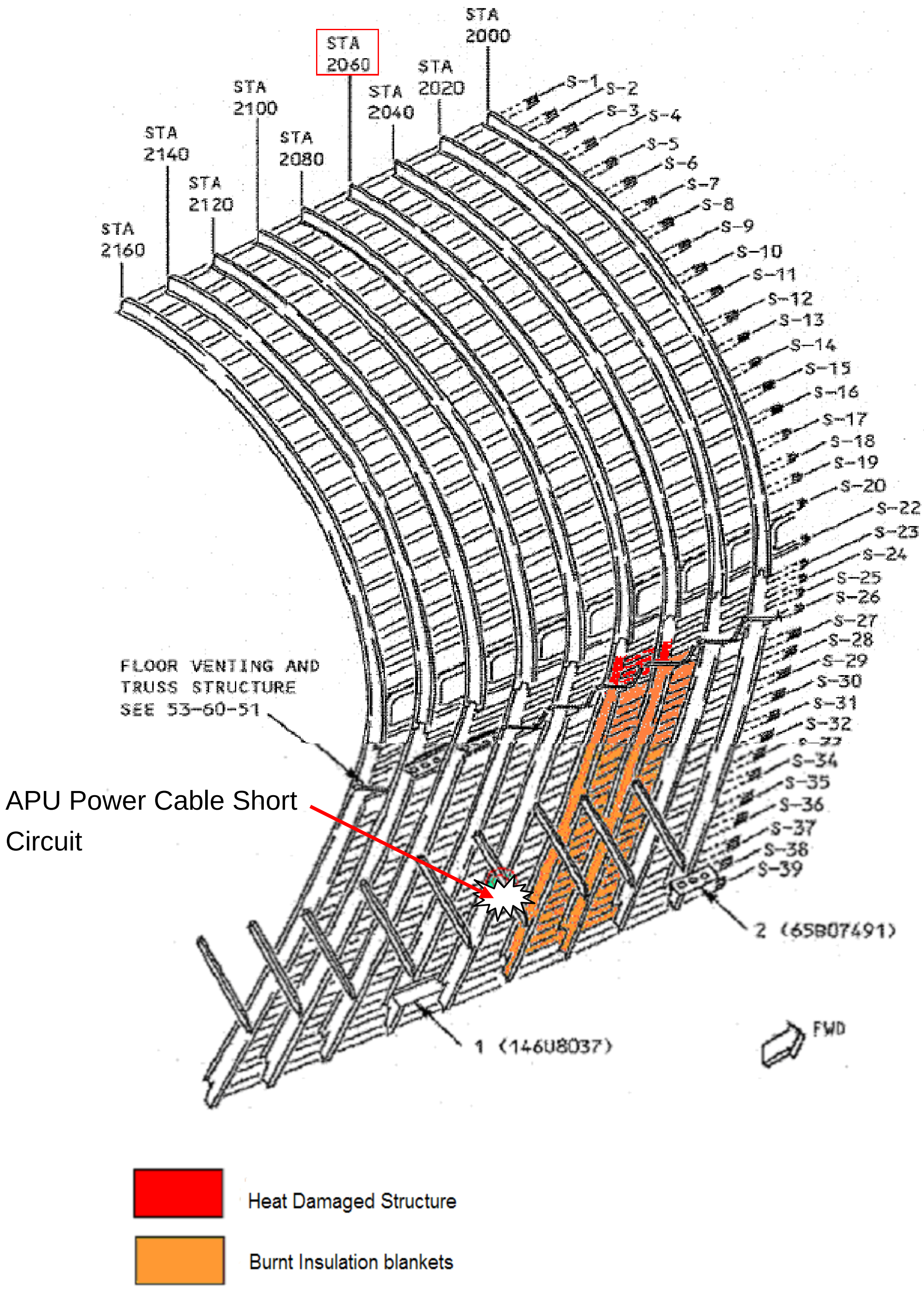


Fig. 1.12-2 Location of Heat Damaged Structure and Damaged insulation Blankets

1.12.1 External of Aircraft

No abnormality was found.

1.12.2 Main Deck Cabin

At the left side of the main deck passenger cabin E zone, between STA 2020 ~ STA 2060, seat number 64A/65A, a side wall panel lower edge seal was found damaged by heat.Near STA 2060 the insulation blanket for this side wall panel was found kinked by heat.The soot over the insulation was also found with smoke trace and discoloration from the bottom to the mid span. See Fig. 1.12-3.

Fig. 1.12-3 Side Wall Panel Insulation Blanket

Cabin area left side, between STA 2040 ~ STA 2060, the insulation blanket behind the side wall panel was also found discolored by smoke; also at the bottom side, the top sheet of the insulation blanket was damaged and detached due to heat. See Fig. 1.12-4. The lower end of the insulation was also burnt and carbonized. See Fig. 1.12-5.

Fig. 1.12-4 Discoloration and Burnt Mark of the insulation Blanket

Fig. 1.12-5 Burnt and Carbonized Insulation Blanket

Smoke trace was also found on the Dado panel adjacent to the side wall panel listed above.

At floor panel below seat number 64A/65A in the E zone of main deck cabin, on the lower surface, between STA 2040 and STA 2060, at the outboard side, it was found carbonized due to elevated heat for an area of 16 inches by 24 inches. Confirmed by tapping test, a delaminated area was also found forward of the STA 2060 floor beam attachment. See Fig. 1.12-6.

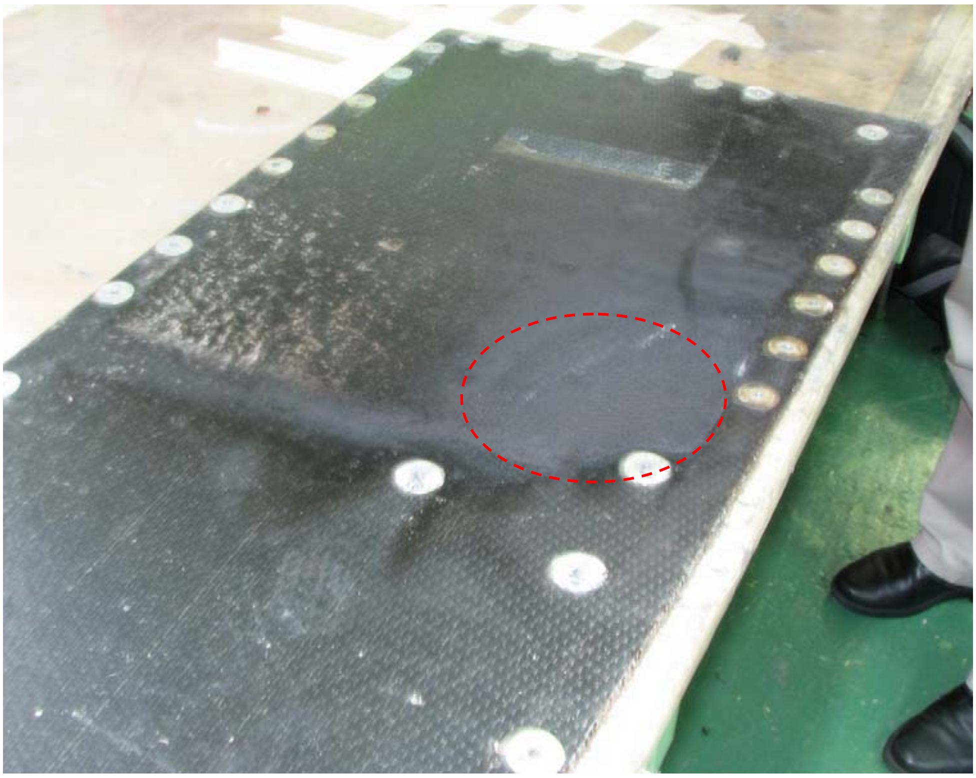


Fig. 1.12-6 Carbonized and Delamination of Floor Panel

1.12.2.1 Under Floor Aircraft Structure

The remaining pieces of the two burnt insulation blankets between STA 2020 and STA 2060 under the main deck floor were collected by EVA for investigation. The two top side face sheets were all consumed by fire whilst the core layer was burnt into pieces with charcoal marks all over. Fire damage of the insulation blankets are shown in Fig. 1.12-7 to Fig. 1.12-10.

Fig. 1.12-7 STA 2020~STA 2040 Damaged Insulation Blanket IB Side

Fig. 1.12-8 Fragment of STA 2040~STA 2060 Insulation Blanket (One Insulation Blanket Image by Three Picture Frames)

Fig. 1.12-9 Face Sheet of Insulation Blanket

Fig. 1.12-10 Charcoaled with Grayish Deposit on Insulation Core Layer

Outboard of bulk cargo compartment side wall lining, those fire damaged insulation blankets and intact ones were examined during investigation. Trace of unknown contamination and dust were found; also in this area, for other aircraft system components, was also found the similar dust accumulation. Below the cargo compartment floor, there were fragments of passenger service items found as shown in Fig. 1.12-11 to Fig. 1.12-18.

Fig. 1.12-11 Contamination, Dust and Cabin Items on the Damaged Insulation Blanket

Fig. 1.12-12 Dust and Traces of Contamination on Insulation Blanket

Fig. 1.12-13 Dust and Traces of Contamination on Insulation Blanket

Fig. 1.12-14 Dust on Other System Components

Fig. 1.12-15 STA 1940~STA 1960 below the Cargo Compartment Floor

Fig.1.12-16 STA 1960~STA 1980 below the Cargo Compartment Floor

Fig. 1.12-17 STA 1980~STA 2000 below the Cargo Compartment Floor

Fig. 1.12-18 Close up View of the Contamination on Insulation Blanket

The face sheet of insulation warp of the pneumatic line for APU, between STA 2040 and STA 2060, was found melted and damaged by heat at OB side. See Fig. 1.12-19.

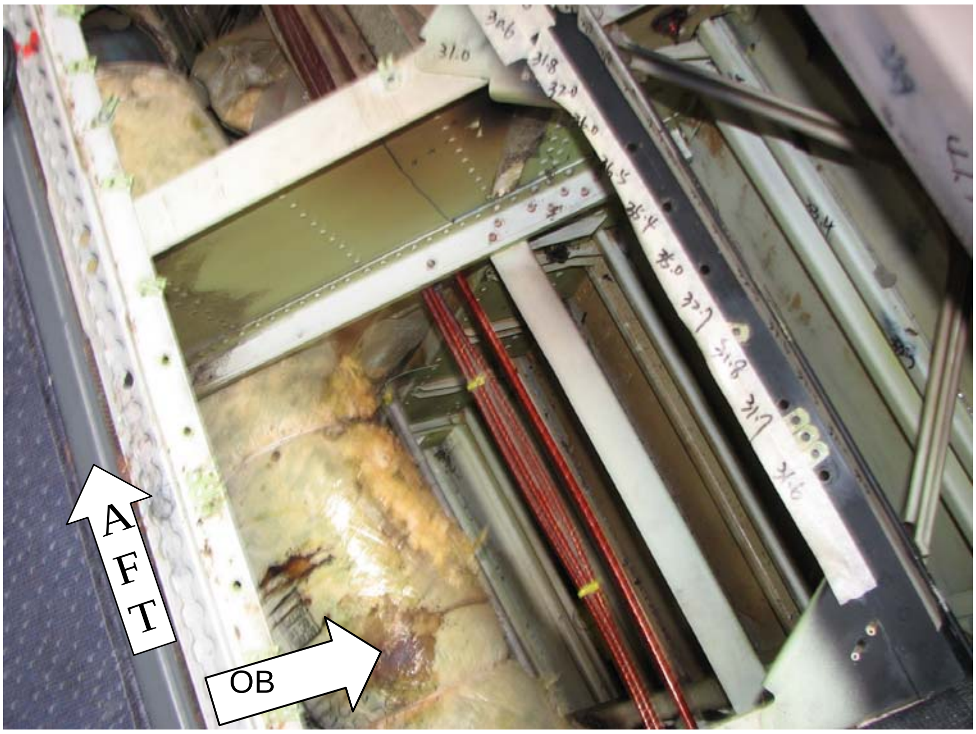


Fig. 1.12-19 Heat Damage of the Insulation of APU Pneumatic Line

One of the three APU power cables, measured 40 inches long between STA 2040 to STA 2080, had been cut and removed in EVA maintenance depot. Within the cut off section, at the point aft of STA 2060, there was a melt and broken spot of the insulation jacket where the maintenance personnel had cut through the cable into two pieces. The melt broken spot measured 7mm in diameter; inside the pit spot the exposed metal core of cable showed signs of charcoal and melted to a 60% depth of the diameter of the metal core, see Fig. 1.12-20 and 1.12-21.

Fig. 1.12-20 APU Power Cable with Damaged Insulation Jacket

Fig. 1.12-21 Cut through View of the Damaged Spot of the Cable

Fig. 1.12-22 illustrated the position of standoffs relative to the fuselage structure, the broken standoff was located at STA 2060 (also refer to Fig. 1.12-1 for damaged insulation blankets versus the damaged APU power cable), in the left lower picture frame showed the standoff had fallen off. By measuring the exact location of these standoffs on the floor beam posts (from STA 2040 to STA 2080), it was found that these standoffs were located with various height against the floor level, among them the STA 2040 standoff and the STA 2060 standoff were at an elevation relatively higher than the others, as indicated in Fig. 1.12-23. The installation method of these standoffs was using two blind rivets, up and down, fixing the base of standoff onto the floor beam posts (see Fig. 1.12-24), whilst the tip of the standoff carrying the APU power cable. ASC investigator measured the load carried by the STA 2060 standoff tip with a spring scale and found it to be 20 lbs downward. Deducted the weight of the APU power cable distributed herein, the excessive load beyond is estimated to be 18 lbs.

Fig. 1.12-22 The Relative Position of The Damaged Standoff to Fuselage Structure

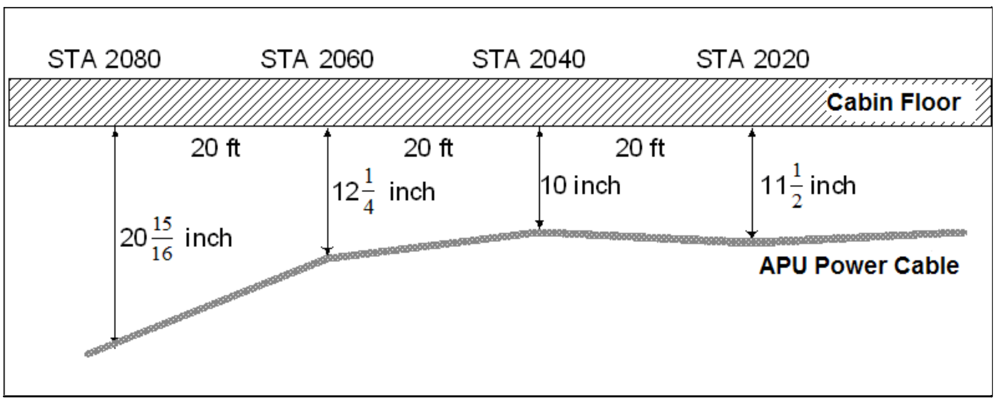


Fig. 1.12-23 Standoffs Located with Various Height to Floor Level

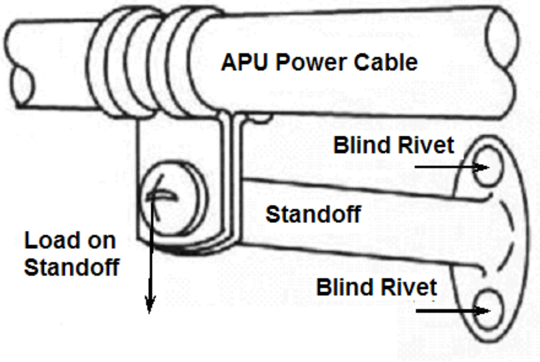


Fig. 1.12-24 Installation Method of Standoffs

The damaged metal standoff, P/N BACN10TL3-18, at STA 2060, LBL 76.61, in fixing the APU power cable had been replaced with a new one, due to the existing fastener holes were enlarged and distorted. New fastener holes were drilled a quarter inch lower relative to the existing ones on the floor beam post, see Fig. 1.12-25.

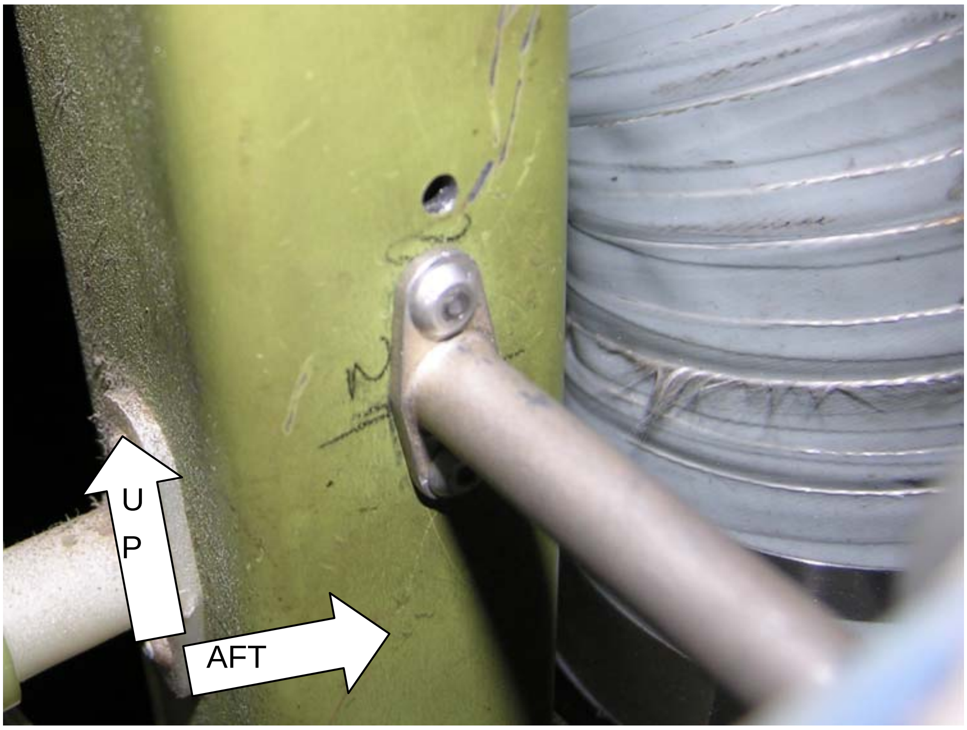


Fig. 1.12-25 New Position of the Replacement Standoff (View looking IB）

Visual check of the damaged standoff during the investigation revealed that the base of the standoff has been bent and torn broken with a downward bending force; the breaking point was at upper side of the base. The lower blind rivet is still attached on the base, see Fig. 1.12-26.

Fig. 1.12-26 The Broken Standoff

The tip of the fastener fixing the tube bracket of the waste tank vacuum pump was found melted, while on the upper surface of the tube running below the melted bolt, some grayish and black power like deposit generated by arcing was found. See Fig. 1.12-27.

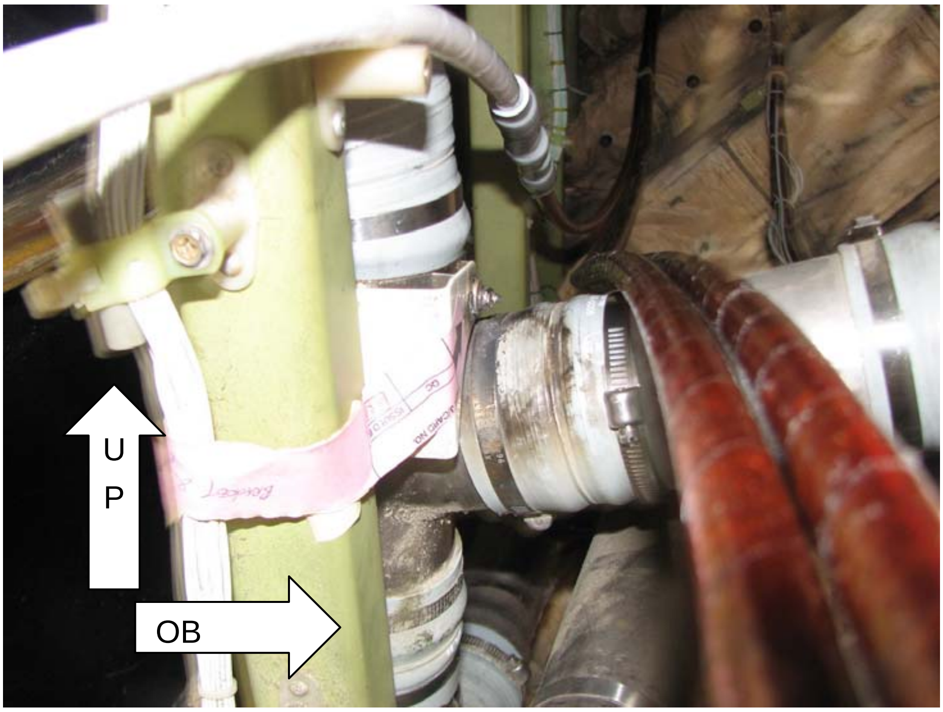


Fig. 1.12-27 Fastener Tip and Deposit generated by arcing（View looking AFT）

The immediate event site photograph is shown as Fig. 1.12-28, which revealed that the standoff base was broke and detached, resulted in the APU power cable touching the vacuum pump tube fastener end at aft of STA 2060.

Repeated abrasion had caused the insulation of the cable to fail and the metal wire to touch the aircraft structure, and caused the presumed arcing condition thereafter.

Fig. 1.12-28 Immediate Photograph of the Site (Provided by EVA)

1.12.2.2 Structure Damage of the Aircraft

Visual Inspection of the Floor Beam

After removal of the fire engorged insulation blankets in the bulk cargo compartment, the floor panel, and the side wall panel in the main deck cabin, it was found that the most left side web and upper chord of the STA 2060 floor beam were discolored with smoke and heat, the discoloration area measured 12.5 inches wide laterally and whole beam width vertically. Another finding was some charcoal remaining fragment of the insulation blanket sticking on the forward surface of the floor beam web and tail end of the S-27L stringer clip, see Fig. 1.12-29 and Fig. 1-12-30.

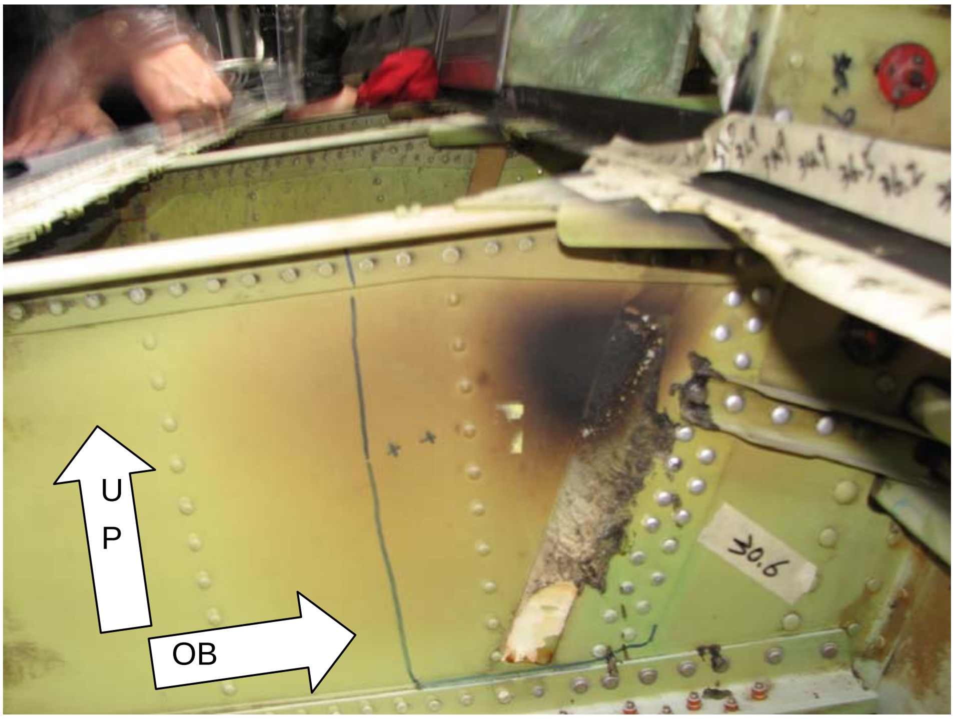


Fig. 1.12-29 STA 2060 Forward Side of Floor Beam

（View looking DOWN & AFT, L/H of A/C）

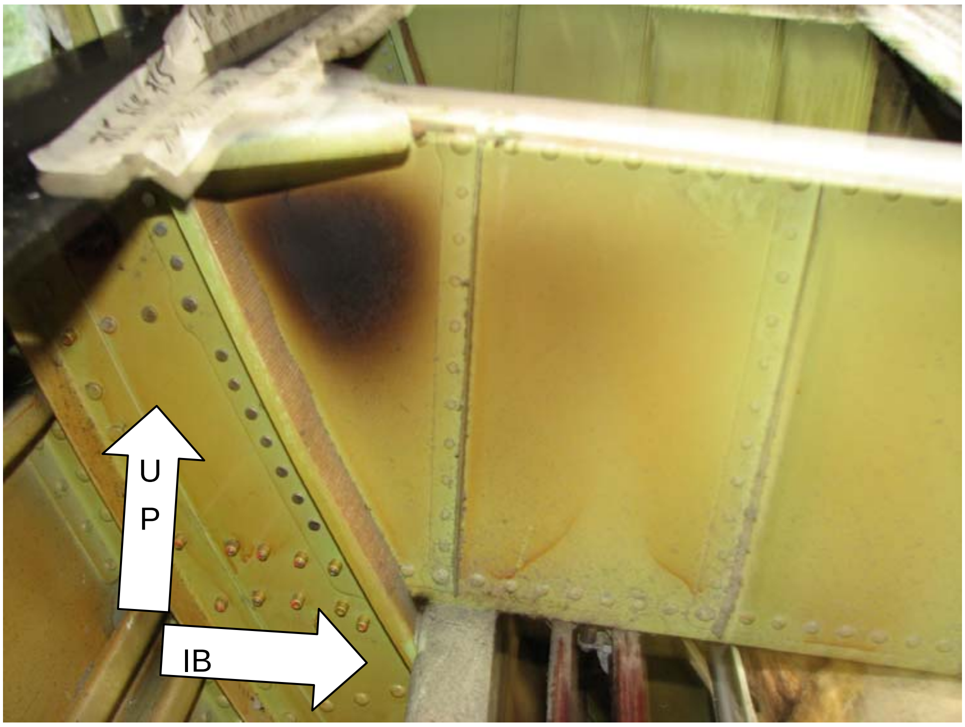


Fig. 1.12-30 STA 2060 Rear Side of Floor Beam

（View looking DOWN & FWD, L/H of A/C）

Visual Inspection of the Left Side Fuselage

Soot and discoloration from heat was found on the STA 2040 and STA 2060 frames between S-24L and S-27L. Stringers namely S-24L, S-25L, S-26L, and S-27L were discolored between STA 2040 and STA 2060. Stringer clips for S-25L and S-27L at STA 2060 were discolored. All heat damage related findings are shown in Fig. 1.12-31.

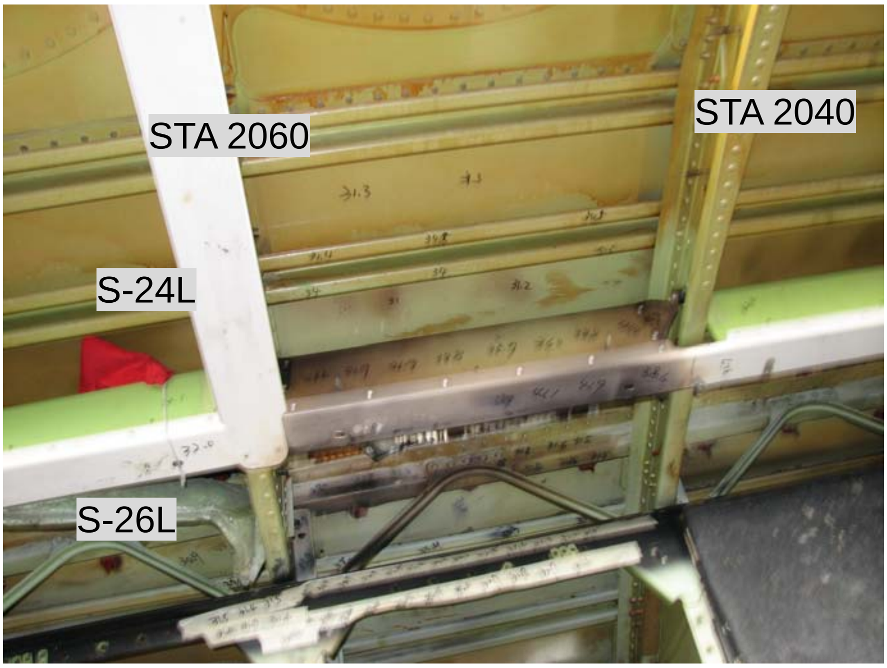


Fig. 1.12-31 STA 2040~STA 2060 Cabin Left Side Structure

In addition, the panel support bracket between STA 2040 and STA 2060 was discolored, as shown in Fig. 1.12-32, item #1.

Stringer S-26L adjacent to the forward side of fuselage STA 2060 frame was found deformed at the upper side stringer flange with elevated temperature, as shown in Fig. 1.12-32, item #2.

Ventilation truss (P/N: 146U5303-3) was found discolored between STA 2040 and STA 2060, as shown in Fig. 1.12-32, item #3.

Mop sill (P/N: 65B06029-1) was found discolored between STA 2040 and STA 2060, as shown in Fig. 1.12-32, Item #4.

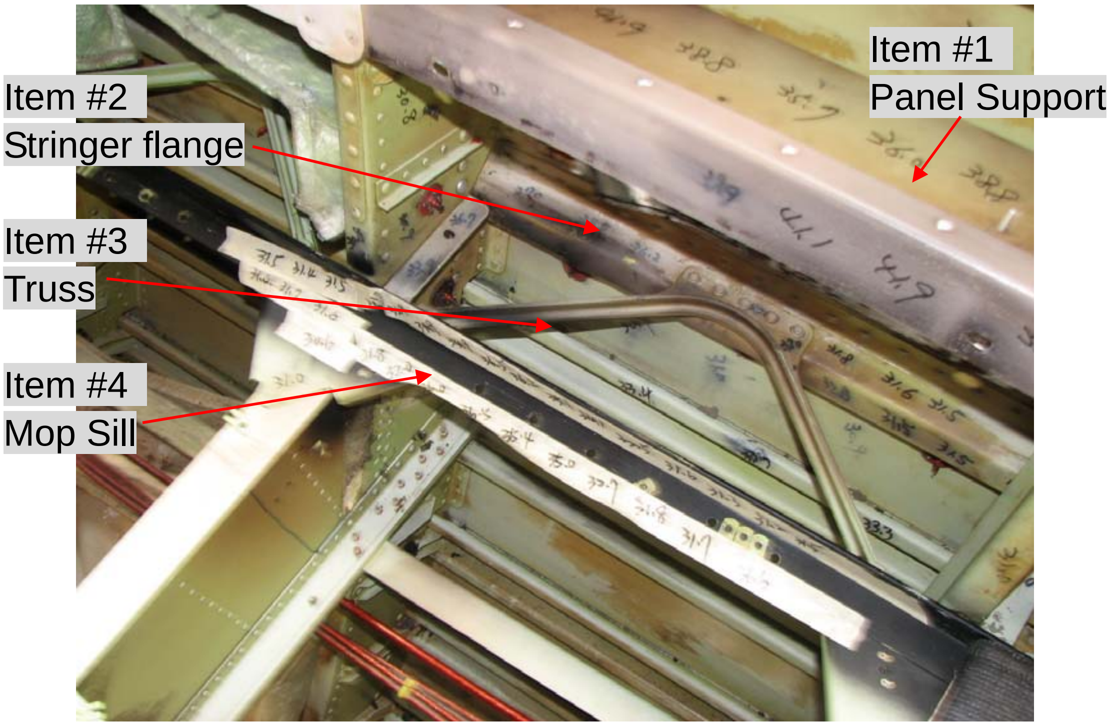


Fig. 1.12-32 STA 2040~STA 2060 Fuselage Left Side Structure

Noise barrier applied between STA 2040 and STA 2060, S-25L and S-26l, was found covered with soot and detached at lower aft corner. See Fig. 1.12-33.

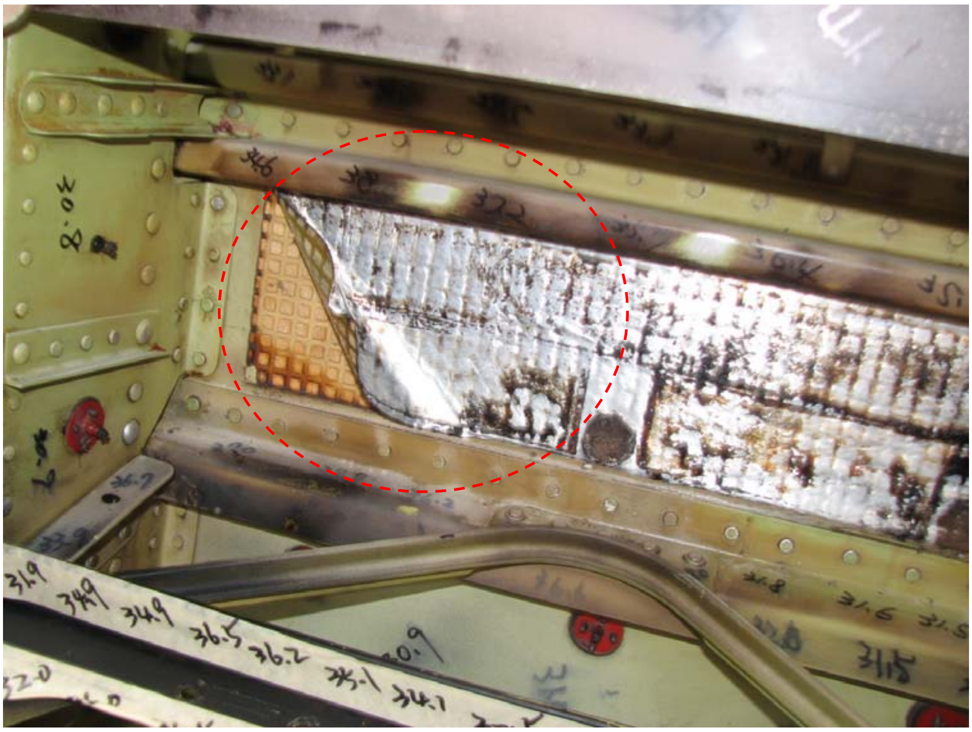


Fig. 1.12-33 Noise Barrier at STA 2040

All structure parts which were found discolored or soot covered were inspected with Eddy Current test and were repaired by Evergreen Aviation Technology Co., Ltd. (EGAT). The inspection results and summary of repair work were listed in Table 1.12-1.

Table 1.12-1 Inspection and Repair List by EGAT

Item	Nomenclature	P/N	Damage Status	Disposition
1	mop sill	65B06029-1	Sta-2049~2060	Repair per SRM 51-70-12
2	S-24L	65B04150-5	Free of damage	NIL
3	S-25L	65B04150-6	Sta-2040~Sta-2060	Repair per SRM 53-00-03
4	S-26L	69B03061-1	Sta-2048~Sta-2060	Repair per SRM 51-70-11
5	S-27L	65B04150-29	Free of damage	NIL
6	F/B-2060 upper chord	65B22651-22	2" length at the LH end	Repair per SRM 51-70-12
7	F/B-2060 web	65B22651-29	Outbd of LBL-104	Repair per SRM 53-00-51
8	Air Baffle Instl, dado panel support angle	411U1323-21	Sta-2040~Sta-2060	Replacement
9	Air Baffle Instl, plate Sta-2040~2060	411U1325-23	entire part	Replacement
10	Air Baffle Instl, plate Sta-2020~2040	411U1365-23	Free of damage	Replacement
11	Air Baffle Instl, angle aft of Sta-2040	65B50988-93	entire part	Replacement
12	Air Baffle Instl, angle aft of Sta-2020	65B50988-93	Free of damage	Replacement
13	Air Baffle Instl, angle FWD of Sta-2060	65B50988-103	entire part	Replacement
14	Air Baffle Instl, angle FWD of Sta-2040	65B50988-103	Free of damage	Replacement
15	Fr-2040	65B04339-109	Free of damage	NIL
16	Fr-2060	65B04340-641	Free of damage	NIL
17	S-25L stringer clip at Fr-2060	65B38600-231	Free of damage	NIL
18	S-27L stringer clip at Fr-2060	65B38600-231	Free of damage	NIL
19	skin	65B04150-2	Free of damage	NIL
20	truss	146U5303-3	Unable to perform conductivity test	Replacement

1.12.2.3 Other Findings

A fleet wide inspection for all the B747-400s of EVA was conducted immediately after the occurrence. One similar case of compromised standoff was found on another sister ship, register number B-16411, with identical APU power cable standoff installed at STA 2060, which the base of the aluminum standoff was found bent downward slightly with a pulled loose blind rivet at the upper side, and the lower blind rivet head clinched. See Fig. 1.12-34.

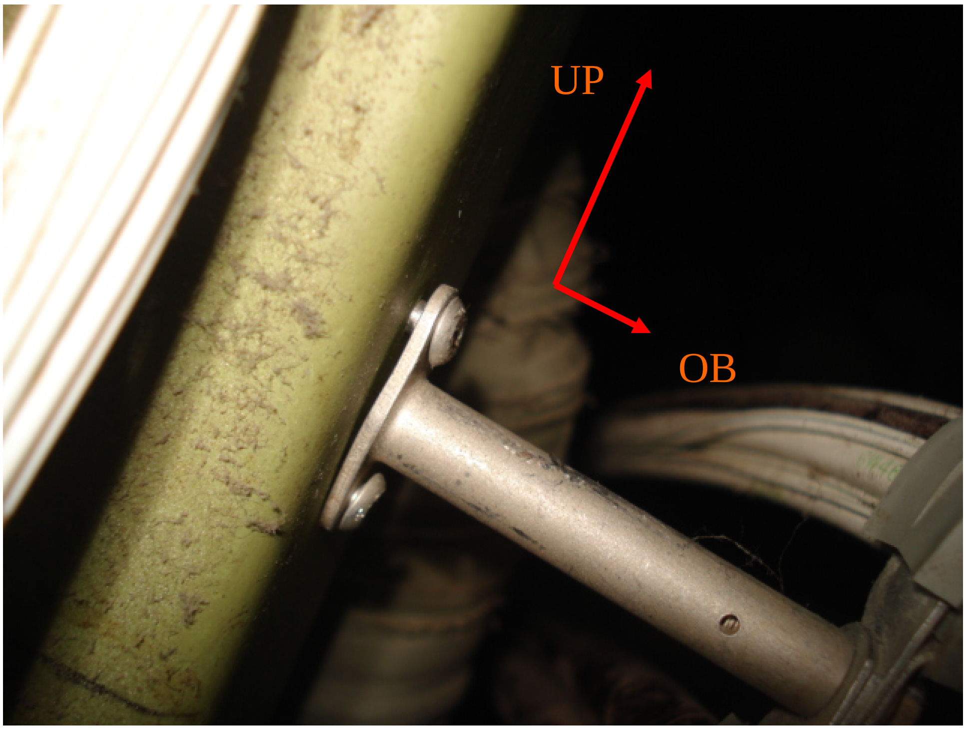


Fig. 1.12-34 Similar Case Found in Fleet Wide Inspection

1.13 Medical and Pathological Information

Not applicable.

1.14 Fire

On Feb. 23, 2008, the aircraft carried out a scheduled flight from Taipei via Bangkok to London. The aircraft landed on Bangkok airport and taxied down to apron. During the moment passengers got off the aircraft, there were smoke coming from DADO panel between seat numbers 64A and 65A. Cabin crew used intercom to inform captain about the smoke. EVA maintenance representative in Bangkok international airport noticed that cabin door L5 was opened. After the representative entered the cabin from the bridge, he saw smoke came from DADO panel between seat numbers 64A and 65A, but no fire was noticed. The representative first went to cockpit to shut down APU and aircraft power. Then he went back to cabin and used a fire extinguisher prepared by cabin crew to spray on the DADO panel where smoke came from. The smoke disappeared gradually. He proceeded to open DADO panel and check source of smoke. Then entered aft cargo compartment to check and make sure the smoke was put out. In next section it was briefly described with damaged conditions. The detail information will be refered to Chapter 1.12 Damage to the Aircraft.

1.14.1 APU Generator Wire Damage

After the smoke put out, EVA maintenance representative started the APU and tried to supply power again. No. 1 APU generator power breaker was tripped and short circuit was found around aft cargo compartment. After inspection, a fell out standoff was found which was resulted from loosed rivets and the broken standoff fixture. One of the three phase electrical wires of No. 1 APU generator rubbed against the attached bolt (refer to Fig. 1.14-1, this figure was taken from another aircraft at the same location, but the upper rivet was loosed) of waste tank tube which resulted in the damage of insulation covering of wire. The damaged insulation covering caused the exposure of metal wire (refer to Fig. 1.14-2).

Fig. 1.14-1 Attached Bolt of Waste Tank Tube Fixture

Fig. 1.14-2 Damaged Cable wire

The contact of exposed cable and bolt resulted in short circuit and the melting of cable condensed into a cascade of melting marks due to the heat (refer to Fig. 1.14-3 and Fig. 1.14-4).

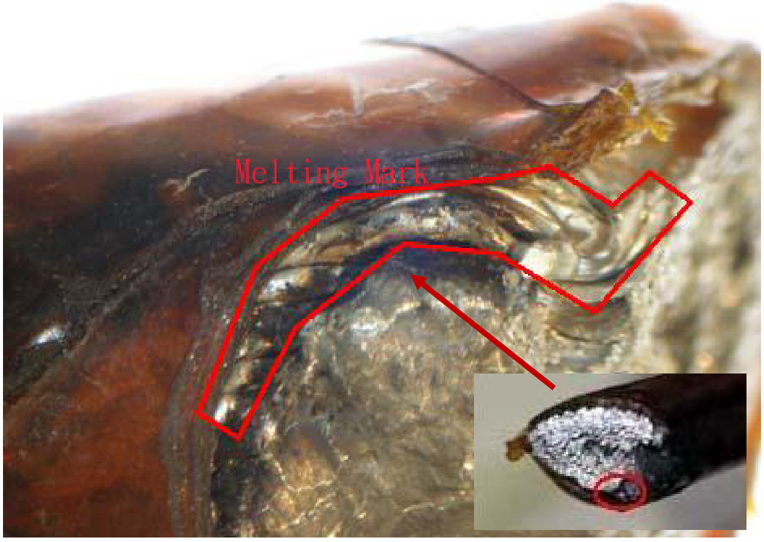


Fig. 1.14-3 Melting Mark of Metal Wire Due to Heat-1

Fig. 1.14-4 Melting Mark of Metal Wire Due to Heat-2

1.14.2 Damage to Insulation Blanket

The distinguishable information such as parts number and date of referred blue print of the replaced insulation blankets (refer to Fig. 1.14-5) due to fire damage were listed as follows.

Fig. 1.14-5 Distinguishable Samples of Damaged Insulation Blankets

Table 1.14-1 Information about Damaged Insulation Blankets

No.	Parts Number	Date of Referred Blue Print	FAR 25.856 Compliance
1	411U4055-1037	12/12/96	Yes
2	411U4120-2020	4/8/96	Yes
3	411U4120-2383	2/21/97	Yes
4	411U4120-2386	2/22/97	Yes
5	411U4120-4312	8/3/97	Yes
6	61B500025-1002	2/14/96	Yes

The damaged and replaced insulation blankets were in cabin and aft cargo compartment covered from station 2020 to station 2060 (refer to Fig. 1.14-6 left Part). The yellow insulation blankets located beneath the wire with damaged insulation covering and short circuit had more serious burnout than other places (refer to Fig. 1.14-6 right Part) while those green insulation blankets installed in cabin were only discolored.

Fig. 1.14-6 Locations and Status of Damaged Insulation Blankets

1.15 Survival Aspects

1.15.1 Cabin Emergency Response

1.15.1.1 Monitoring and Notification

According to the interview of cabin crewmembers, after the aircraft taxied to the gate, the flight crew shut down the engines and the cabin crew transferred the main cabin doors mode to manual position respectively. In the meantime, most of the passengers had stood up from their seats to take their hand luggage and were waiting to disembark. A passenger at rear side of cabin noticed smoke and notified to L5 cabin crew (duty code of cabin crew, see figure 1.15.1). L5 cabin crew discovered that white smoke with hot air was emitting from the left DADO Panel of seat A in row 64 to 65. Because passengers were being jammed in the aisles, the L5 cabin crew remained on scene to monitor smoke, warned passengers to stay away from the smoke and then asked R5 cabin crew to report to the cabin chief. L5 cabin crew also asked L4' cabin crew to assist R5 cabin crew in guarding L5/R5 main cabin exits (see Figure 1.15.2). L4' cabin crew also reported to L4 cabin crew (E zone chief) about the smoke.

After the confirmation, L4 cabin crew asked R4 cabin crew to inform cabin chief via interphone who was at the L1 door. At that time, the passengers in business class cabin (A, B Zone) and evergreen deluxe class cabin (C Zone) had already disembarked. The passengers in the upper deck, around 20 passengers were disembarking in order. (A, B, C, Upper Deck, D and E Zone, see figure 1.15.2)

R5 Cabin Exit Opened by Passenger

As requested by L5 cabin crew, R5 cabin crew tried to inform the cabin chief via interphone but couldn't success. R5 cabin crew then called L2 station and told L2 cabin crew about smoking in E zone. At that time the smoke was becoming dark and thick. A male passenger asked cabin crew to open the main cabin door. R5 cabin crew replied that they should wait for instruction from the captain. Suddenly, the passenger opened R5 exit by himself (the slide did not deploy due to the door was in manual position). L4 and L4' cabin crew came from the smoking scene to assist and prevent passengers from falling out of the aircraft.

1.15.1.2 Response of Flight Crew

After the cabin chief informed by R4 cabin crew, the cabin chief reported to the captain immediately. The Captain acknowledged the information. According to interview questionnaire and answer, Captain then directed the first officer to deal with the smoke in cabin. Due to passengers were disembarking, the first officer was blocked and stayed around L1 and L2 exits and assisted to disembark passenger. When the first officer arrived the E zone, the maintenance representative was already there.

1.15.1.3 Response of Cabin Chief

When cabin chief tried to approach to E zone, C/D zone and D/E zone were divided by curtains. According to EVA's rules, unless an emergency, after the fasten seat belt sign is off, the curtains should be closed, cabin chief said. Base on cabin chief interview records, cabin chief tried to rush to the scene after receiving notice but failed. The aisles were jammed by passengers in D zone. Passengers in D zone didn't smell or notice the smoke from E zone because of the closed curtain. The closed curtain also obstructed the cabin chief's sight to E zone. Therefore cabin chief instructed cabin crew to open the curtains that divided C/D zone and assist D zone passengers to disembark quickly.

1.15.1.4 Passenger Evacuation and Cabin Fire Fighting Preparation

After R5 door was opened by a passenger, L4 cabin crew guarded the R5 door and guided passengers to move forward. Around twenty passengers queried why the slide did not deploy after the door was opened. They couldn't wait to evacuate in R5 door because smoke became darker and thicker. While L4 cabin crew insisted that passengers had to disembark through the front cabin door , then most of the E zone passengers got off the aircraft accordingly to move forward. Based on cabin crews' interview records, the cabin crew could not see row 69 seats from row 61. Afterwards, the captain contacted L5 station via interphone and gave instruction to L4' and L5 cabin crew to prepare fire extinguishers and smoke hoods to standby.

1.15.1.5 The L4 door Opened by Passenger

After the smoke occurred, the L4 an L4' cabin crew left their duty locations individually to assist E zone. While guided the passenger to move forward, L4 cabin crew found the L4 door had been opened by passenger.

1.15.1.6 The Fire Extinguished in Cabin

When the cabin chief arrived E zone, all passengers had disembarked. Some cabin crew already prepared the fire extinguishers and smoke hoods taken from L3, L5 exits and standby at the site. The others collected all the passengers' remaining stuffs in cabin to L2 exit. When captain arrived, he asked all cabin crew to disembark except the cabin chief. The fire was eventually extinguished by maintenance representative.

1.15.1.7 Others

All lavatories equipped with smoke detectors. Neither signal nor sound of warning observed during the occurrence and no cabin announcement was made after the occurrence. The cabin chief stated in interview that the reason for not initiating the emergency evacuation was based on their judgment of the occurrence's nature.

The estimate time from the initial occurrence notification to the completion of passenger disembarkation was about two to three minutes.

See Appendix 2 for passenger statement of the occurrence.

1.15.2 Cabin Layout

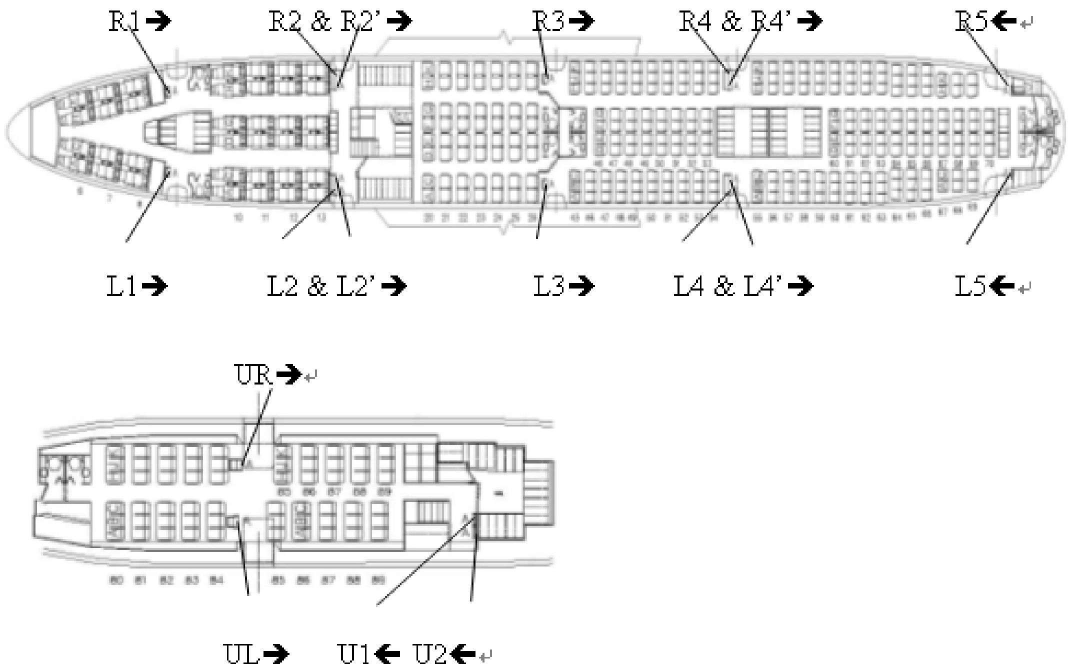


Fig. 1.15-1 The assigned seats of the cabin crew

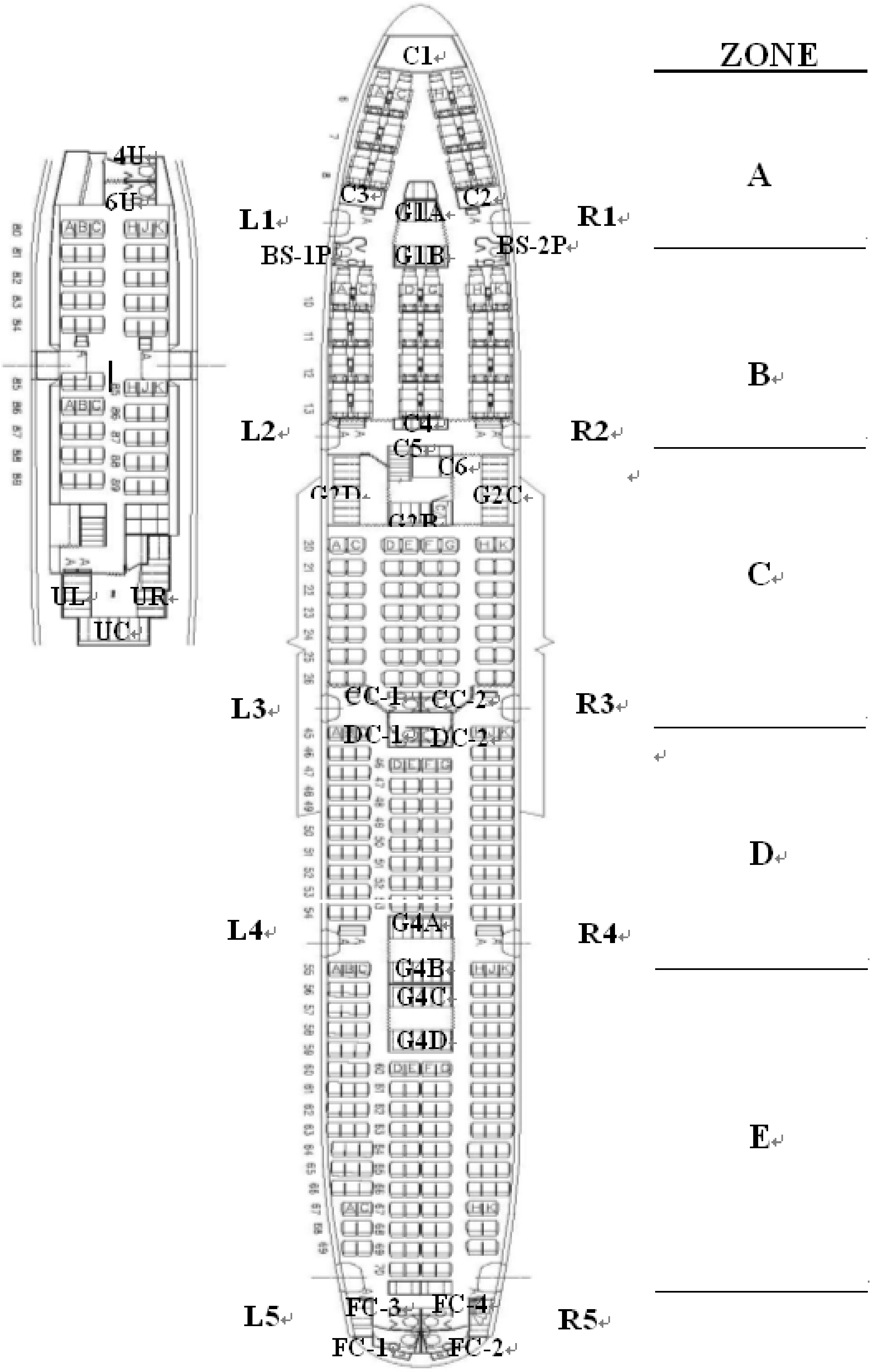
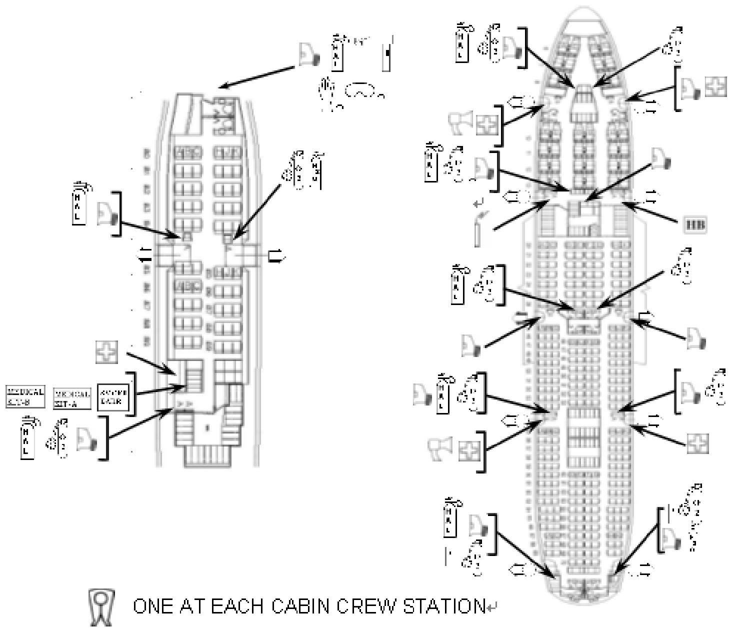


Fig. 1.15-2 Cabin Zone



Pull Down Stowage Bin	R2 Aft	R3	R4	U/D Closet
	1	1	1	1
	5	--	--	--
Infant	15	--	--	--

ONE AT EACH CABIN CREW STATION

ONE AT EACH PAX'S SEAT

ONE NEAR BY EACH CABIN CREW STATION

Fig. 1.15-3 The location of emergency equipment

Table 1.15-1 The emergency equipment list

A. **Emergency equipment checklist**

ITEM	DESCRIPTION	QTY	LOCATION
1	Smoke Goggles	2	(2) Near by 1st and 2nd observer
2	(a)Vented Full Face Oxygen Mask (b)Vented Oxygen Mask	2 2	(2) Captain and First Officer (2) 1st and 2nd observer
3	Crash Axe	1	(1) 2nd observer L/H AFT compartment
4	Inertia reel Descent Device	4	(4) 1st observer overhead compartment
5	Life Vest (Crew)	22	(4) Each flight crewmember seat (18) Each cabin crew seat
6	Life Vest (PAX) Life Vest (Spare)	370 5	(368) Each PAX seat (2) R5 door crew rest seat (5) R2 door AFT pull down bin
7	Life Vest (Infant)	15	(15) R2 door AFT pull down bin
8	Baby Cot	0	
9	First Aid Kit	5	(4) R1, L1, R4, L4 door pull down bin (1) U/D closet near stair
10	Medical Kit--A	1	(1) U/D closet near stair
11	Medical Kit--B	1	(1) U/D closet near stair
12	Halon Fire Extinguisher Kidde 090052	9	(1) 2nd observer L/H AFT compartment (1) Dog house stowage near L1 door (1) Dog house stowage FWD of L2 door (2) L3, L4 door crew seat (1) L5 door crew seat (1) R5 door overhead crew bunk (1) U/D L/H door crew seat (1) U/D L/H stowage neat closet
13	Water Fire Extinguisher	7	(1) Dog house stowage near R1 door (2) R3, R4 crew seat (1) Dog house FWD of R2 door (1) R5 door under stair stowage (1) R5 door overhead crew bunk (1) U/D R/H door crew seat
14	Portable Oxygen Bottle	13	(2) Cage mounted container FWD of R1, L1 door (2) Dog house stowage FWD of R2, L2 door (4) Floor mounted container FWD of R3, L3, R4, L4 door (1) R5 door under stair stowage (1) Lower closet AFT of L5 door (2) U/D 9 HK overhead bin (1) U/D L/H stowage near closet
15	Smoke Hood (PBE) Drager Puritan-Bennett	14 1	(2) Dog house stowage near R1, L1 door (2) Dog house stowage FWD of L2, R2 door (4) R3, L3, R4, L4 door crew seat (1) R5 door under stair stowage (1) L5 door crew seat (2) U/D R/H, L/H door crew seat (1) U/D L/H stowage near closet (1) 1st observer AFT wall (1) R5 door overhead crew bunk
16	Flashlight	21	(16) Cabin crew seat except near door 5 (1) R5 door under stair stowage (1) L5 door crew seat (1) R5 door overhead crew bunk (2) Cockpit AFT sidewall
17	Megaphone	2	(1) L1 door pull down bin (1) L4 door pull down bin
18	Emergency Locator Transmitter (E.L.T.)	1	(1) L2 door AFT pull down bin
19	Fire Resistent Gloves	6	(2) 2nd observer L/H AFT compartment (1) R2 door AFT pull down bin (1) R3 door pull down bin (1) R4 door pull down bin (1) U/D closet near stair
20	Demo Kit: Demo Life Vest Demo 02 Mask Demo Seat Belt Stowage Bag	14	(2) U/D L/H stowage near closet (3) Compartment No.219 of purser work station (5) Dog house stowage FWD of CC-1 LAV (4) Dog house stowage FWD of AFT CTR closet (L/H)
21	Extension Seat Belts	10	(5) Compartment No.219 of purser work station (5) R5 door under stair stowage
22	Baby Bassinet	8	(4) Nose closet (4) AFT CTR closet (L/H)
23	Hygienic Bag	1	(1) R2 door FWD pull down bin
24	Spare Seat Cover (SB & ED)	2 kits	(2) L3 door pull down bin
25	Security File	1	(1) Compartment No.218 of purser work station

1.15.3 Cabin Crew Training

All (14) cabin crewmembers' annual recurrent trainings and check requirements were complied with the Civil Aviation Regulations. The course curriculums include emergency equipments review, door operation, and safety check, usage of the First Aid Kit, emergency drill and fire fighting.

1.16 Tests and Research

1.16.1 Test of Standoff

The APU power cable standoff was sent to Chung-Shan Institute of Science and Technology (CSIST) for further examinations and tests on June 4 2008. The examination report was documented as in Appendix 3.

Refer to figure 1.16-1, it shows the APU power cable standoff. Following examinations and tests were macro observation and photographic documentation, chemical analysis, microstructure inspection, micro-hardness tests, and Scanning Electron Microscope (SEM) examination on fracture surface to determine the root cause of failure. The following sections summarized the results of the examinations and tests.

Fig. 1.16-1 the APU power cable standoff

Figure 1.16-2 shows the macro observation and photographic documentation of fracture surface of the standoff. The arrow shows the lower ear of the standoff and it reveals the bending features, and furthermore it reveals the fracture features obviously in the upper ear of the standoff. Inspecting the surface of the upper ear (surface A, near the APU power cable), some rubbing marks are found, shown in figure 1.16-3(a). Inspecting the back of the upper ear (surface B, near the wall), there are some clear pressing marks as shown in figure 1.16-3(b). The thickness measurement results of the straight part and ear part of the standoff are corresponding with the requirement.

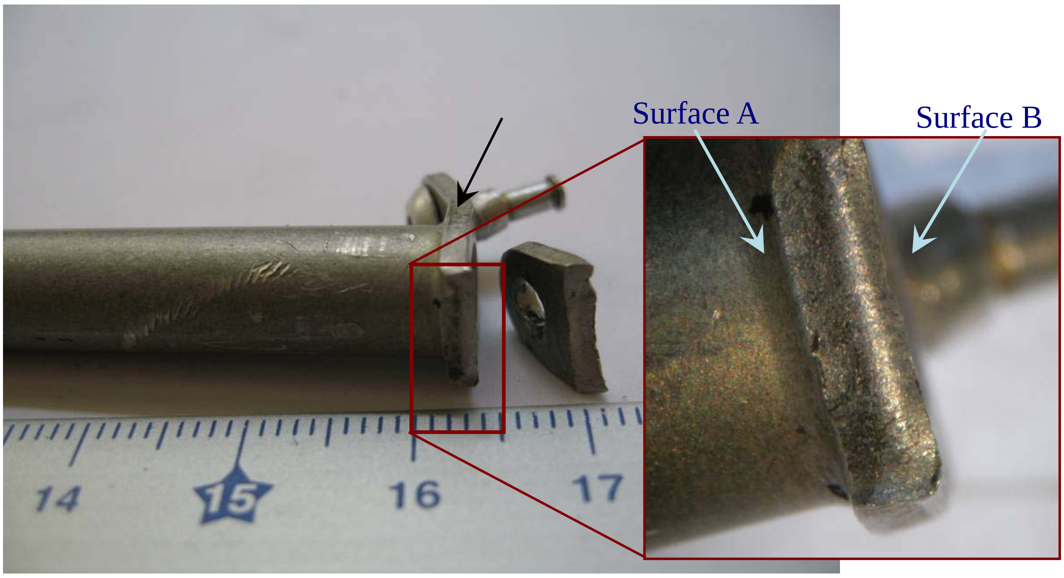


Fig. 1.16-2 Macro observation of the standoff

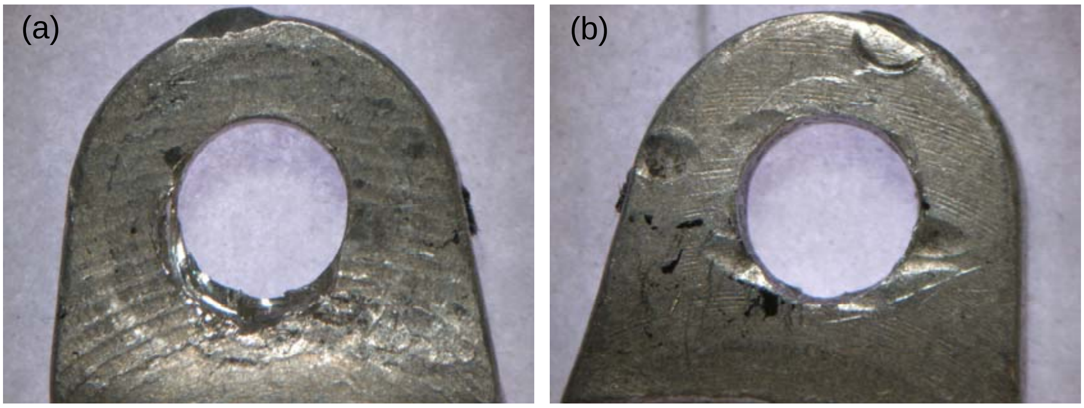


Fig. 1.16-3 Macro observation of the upper ear

The fracture surface examined by Scanning Electron Microscope (SEM) was shown in figure 1.16-4. Figure 1.16-4(b) showed enlarged morphology of the red line framed region in figure 1.16-4, fracture surface near the upper part (near surface A) was quite rough, but fracture surface near the lower part (near surface B) was flat. The SEM photographs at higher magnification showed worn heavily. Figure 1.16-4(c) showed enlarged morphology of the blue line framed region in figure 1.16-4, local ductile dimple-fracture region were found, and the region was supposed to be the final overload fracture.

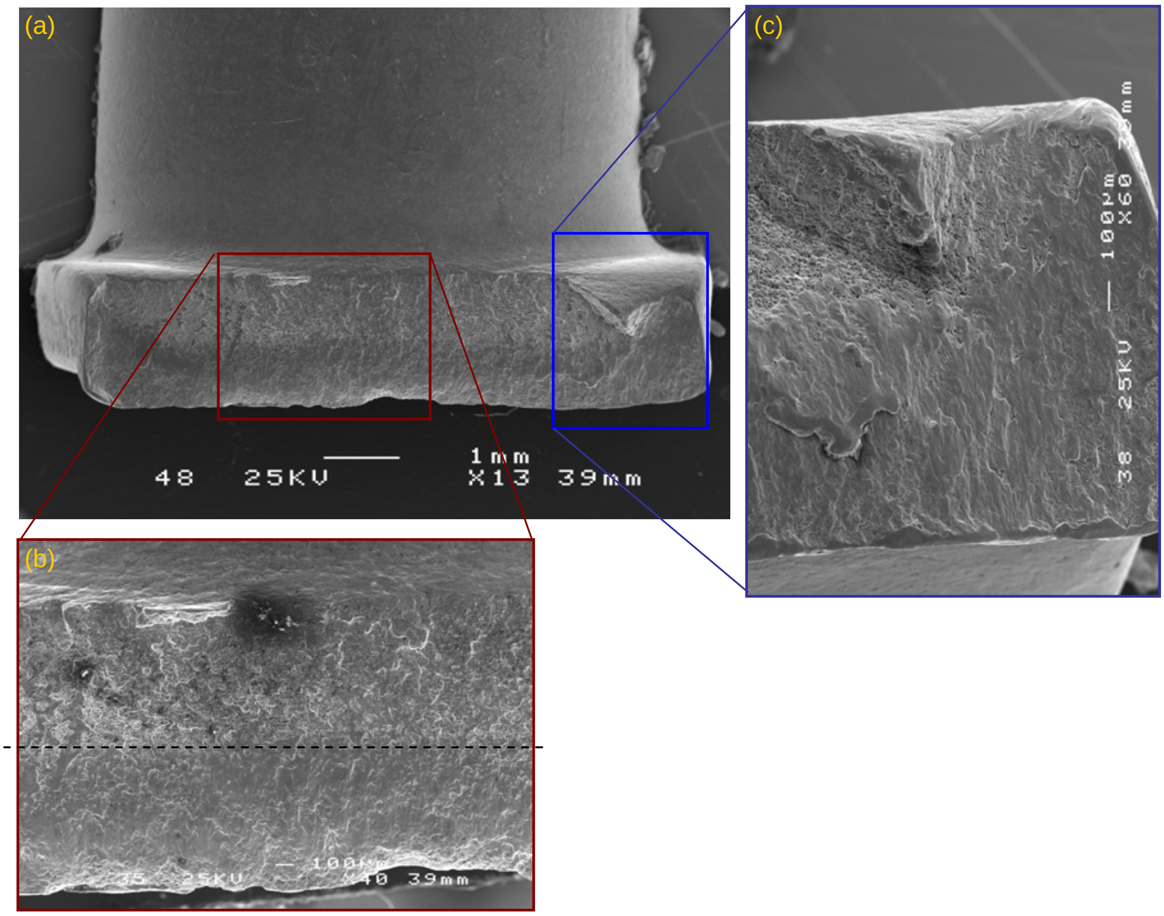


Fig. 1.16-4 Fracture surface examined by SEM

Figure 1.16-5 showed the microstructure of the longitudinal section of the lower ear of the standoff, and the standoff was formed by forging with normal grain size. There was a micro-defect at the corner. The sample was analyzed by an EPMA (Electron Probe Micro-Analyzer) with the results shown in table 1.16-1. The material of the sample met the required 6061-T6 aluminum alloy specification due to the results of the microstructure inspection and micro-hardness tests.

Table 1.16-1 Chemical analysis

Element	Mg	Si	Cr	Mn	Fe	Cu	Zn	Ti	Al
Wt% Content	0.81	0.53	0.19	0.03	0.22	0.32	0.02	0.02	Rem.

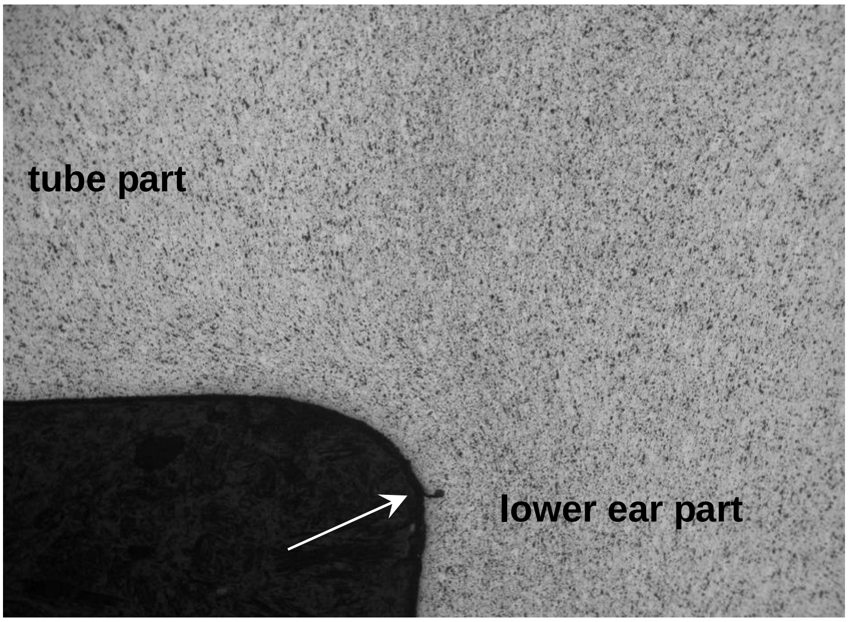


Fig. 1.16-5 Micro-defect characteristics

In order to confirm the fatigue striation characteristics, fracture surface examined by SEM was conducted at by Graduate Institute of Materials Science and Technology, National Taiwan University of Science and Technology (NTUST). It showed that the back of the upper ear (surface B) was quite rough, and some micro-defects are found, shown in figure 1.16-6. More spares were inspected, and the some micro-defects were found in the ear part (surface B), shown in figure 1.16-7.

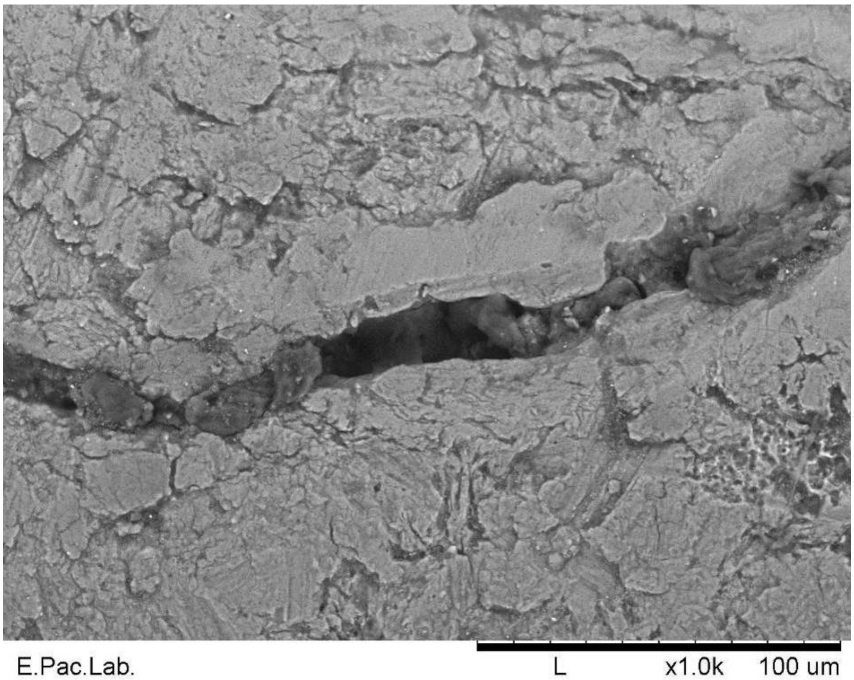


Fig. 1.16-6 Micro-defect on the back of the upper ear

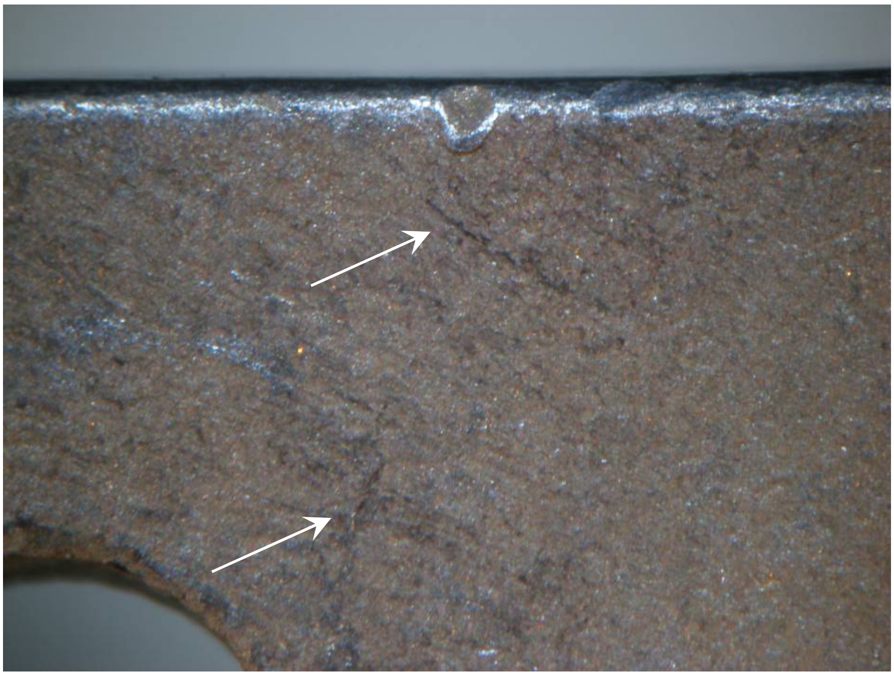


Fig. 1.16-7 Micro-defect on the back of ear part of the spare

1.16.2 Test and Research of Insulation Blanket

The damaged insulation blankets, undamaged but contaminated insulation blankets removed from the same aircraft and spared new samples were sent together to the National Transportation Safety Board (NTSB). The NTSB then divided certain activities between the fire laboratory of the Federal Aviation Administration of US (FAA) and the materials laboratory at Boeing to conduct related inspections and tests. NTSB personnel participated in these tests to support ASC. FAA fire laboratory's test was mainly on the fire test of insulation blanket. Boeing's tests included the analysis of the surface film of insulation blanket and the composition of contamination on insulation blanket. Test results were summarized as follows. Detail report refers to Appendix 4.

The surface film of the blankets was a non-metalized Mylar thinner film surface. Through Fourier Transform Infrared Spectrometer (FTIR) analysis, the surface film was identified as Polyethylene Terephthalate (PET). The contaminations on the insulation blanket were a mixture of corrosion inhibiting compounds (CIC), synthetic and natural fibers, animal hairs, cellulose fibers, mineral particles, Styrofoam, metal fragments, and insects etc.

Vertical strip burn tests[5] revealed that the skin material of the used blankets could ignite but the spread of flame was slow and would extinguish within the

[5] The test was conducted in accordance with the method specified in FAA "Aircraft Materials Fire Test Handbook", Chapter 1 Vertical Bunsen Burner Test for Cabin and Cargo Compartment Material.

permissible 15 average seconds. Cotton swab burn tests[6] revealed that the contamination could burn on the surface of the blanket and involve the surface beyond the permissible eight inches.

Test report concluded that the insulation blanket conformed to the required specifications, but the contaminated insulation blanket failed the cotton swab burn test.

Fig. 1.16-7 Burn Test of Insulation Blanket

1.17 Organizational and Management Information

Not applicable.

1.18 Additional Information

1.18.1 Flight crew Interview

1.18.1.1 CM-1

[6] The test was conducted in accordance with the method specified in FAA “Aircraft Materials Fire Test Handbook”, Chapter 22Cotton Swab Test for Thermal Acoustic Insulation Blankets. It is a non-regulatory test but widely used by aviation company in the fire resistance test of thermal acoustic blanket.

Two to three minutes after the aircraft was stopped, engines shutdown, and engine shutdown checklist was completed, the chief purser and one cabin crew noticed cockpit via interphone that there was smoke in the cabin. CM-1 checked the overhead panel at that time, except APU Generator 1 “AVAIL” indicator was not illuminated, all indication of other indicators were normal.

CM-1 directed CM-2 to economic class to check the condition and cooperate with cabin crew and ground staff to handle the situation. After that, CM-1 reached cabin to assist passengers disembarking the aircraft via L1 and L2 aerobridge.

1.18.1.2 CM-2

Everything was normal throughout the flight including taking-off from Taipei, cruising, approaching, and landing at Bangkok International Airport. While taxing close to the parking bay, CM-2 turned on the APU in accordance with the procedure. When the aircraft parked at space, CM-2 discovered no APU PWR1 indication, APU PWR2 was providing the electrical power. After completed the engine shutdown procedure, except the indication of APU GEN No.1 not available, there was no other warning indication. When CM-2 was discussing with CM-1 about the situation mentioned above, chief purser called to notice that there was smoke in the economic class. CM-1 directed CM-2 to cabin to check the situation and to report to him. CM-1 stayed in the cockpit to make decision and communicated with outside parties. When all passengers got out of the aircraft, the local EVA maintenance representative discharged the fire extinguisher toward the smoking area. Crew then continued to handle the matter in accordance with the SOP.

1.18.2 Summary of Interview with Maintenance Personnel

1.18.2.1 Maintenance Personnel

The latest scheduled maintenance check for the area with the compromised APU power cable was the Zonal Inspection (Job card No. 1A62IN) on 20th August 2004. Interview for the foreman leading this work assignment is summarized as below:

The task manpower assignment for this job card was a team of two or three mechanics, who will remove the access panels and clean the inspection area as required. With visual inspection, and if not able to visually check directly, they would check by hand feel to verify the soundness of the item being *inspected; for structure inspection, the inspection areas were cleaned and visually checked with the aid of torch light and mirror.*

Inspection aids the foreman used to carry were torch light, inspection mirror, solvent, CPC, and scratch stick for sealant removal.

The foreman when leading this zonal inspection, divided his team members to the work accordingly with each individual mechanic ripping the access panel, cleaning the inspected zone, inspecting, and restoring the inspected zone alone themselves. In conclusion, the foreman rechecked the work before notifying the authorized DQC to buy off the task with a numbered triangle stamp.

The foreman was not able to recall who were the team members at the particular zonal inspection, however he assured that the three crews were sheet metal skilled.

1.18.2.2 Bangkok Maintenance Representative

On Feb. 23, 2008, this aircraft carried out a flight from Taipei via Bangkok to London. The aircraft landed on Bangkok airport and taxied down to apron. During the moment of passengers getting off the aircraft, there were smoke coming from DADO panel between seat numbers 64A and 65A. After cabin crew used intercom to inform captain about the smoke, EVA maintenance representative on site Bangkok airport presented. The representative used a fire extinguisher of the aircraft to spray on the smoke. The interview was done through telephone.

The representative saw the aerobridge had connected to aircraft, however, with L4 and L5 doors opened. After entering cabin, the representative saw smoke came from DADO panel and side wall between seat numbers 64A and 65A, but no fire was noticed. The representative first shut down the APU and aircraft power, then used one of the nearby two bottles of fire extinguishers prepared by cabin crew to spray on the DADO panel where smoke came from. The smoke disappeared gradually. The representative proceeded to open DADO panel to check the source of smoke. Then entered aft cargo compartment to check and find the smoke was disappeared.

In order to identify smoke source and the location, EVA Taipei headquarters permitted to do trouble shooting on the aircraft. First shut off ground power. Then, restarted APU and found No. 1 APU generator power breaker was tripped. Electrical arcing was found on APU ground wire around aft cargo compartment. After inspection, the arcing was originated form the region near waste tank compartment. Because of loosed rivets and broken standoff fixture, the standoff fell off. One of the three phase electrical wires of No. 1 APU generator rubbed against the attached bolt of waste tank tube which resulted in the damage of insulation cover of wire. The damaged insulation cover caused the exposure of metal wire to contact the bolt and resulted in a short circuit. The short circuit resulted in the smoke from the insulation blankets at the bottom of aft cargo compartment.

The representative stated that after a thorough check of the waste tank compartment area, only heat damaged insulation blankets were found. The skin surface of aircraft structure was discolored, but erasable by hand. Therefore, aircraft structure was inferred without damage. There were no abnormality to near cabin floor and its structure was not checked. All other systems were verified normal. APU was deactivated and the damaged insulation cover was insulated. The aircraft was then released to fly.

2 Analysis

2.1 APU Generator Wires and Standoff

2.1.1 Damage to the Standoff

As specified in 1.16.1, the breakage at the upper lug of the standoff base plate (Fig. 1.16-4), signs of compression failure can be observed at the lower half (the side near the floor post, side b) of the rupture section, whilst the signature of ductile failure, dimple like failure surface, was observed at the upper half (the side near the wire, side a) of the failure cross section. It is concluded that the compression failure occurred at the first stage, resulted in reduction of the residual strength of the base plate and subsequent ductile overload failure of the upper half. Immediately, when the breakage of the upper lug, with no retention at the top side, the carried load was then concentrated on the lower fastener solely and caused the deformation of the lower lug of the standoff.

2.1.2 Stress over the Standoff

An observation of the relative position of the failed STA 2060 standoff to the neighboring ones, the failed standoff was found located at a cable routing with large variation of elevation, besides, multiple cable with different length were fixed onto this standoff altogether. It is obvious this standoff will be much more heavily loaded than the neighboring ones. With the aircraft on ground stationary, investigation team measured the load carried by the standoff and found the load was 20 lbs downward. See Figure 1.12-23 ~ 1.12-26.

The finite element analysis (FEA) is implemented to evaluate the stress distribution of the standoff. First step is to create the geometric model of standoff (figure. 2.1-1), and then setup the boundary condition of FEA, such as load and support condition. In this case, we perform a static structural simulation under a load of 20 lbs, there in assuming that there is no fracture in the standoff and the rivet, computing the stress distribution and analyzing the root cause of failure. Refer to figure 2.1-2, it shows the distribution of principal stress of the standoff, the maximum tensile stress on the surface A of the upper ear is 334MPa[7] and the maximum compress stress on the surface B of the upper ear is 26.1MPa, wherein the Yield Stress of 6061-T6 aluminum alloy is 276MPa and the Ultimate Stress is 310MPa[8]. According to the simulated

[7] MPa = Mega Pascal. 1 MPa = 10^6 Newton/m^2

[8] The 20 lbs of load was measured while the aircraft was on ground. The real

result of FEA, the initial fracture is indicated on the surface A of the upper ear, while the standoff is well installed and there is no defect on the standoff. The simulation is based on a static load of 20 lbs, and it may cause more damage resulting from the vibration and tightness of APU cable due to normal operation of the aircraft. As specified in chapter 2.1.1, the local ductile dimple-fracture region (the side near the wire) is found, and is supposed to be the final overload fracture. It is not corresponding to the simulated result of FEA, so that the boundary condition is needed to modify.

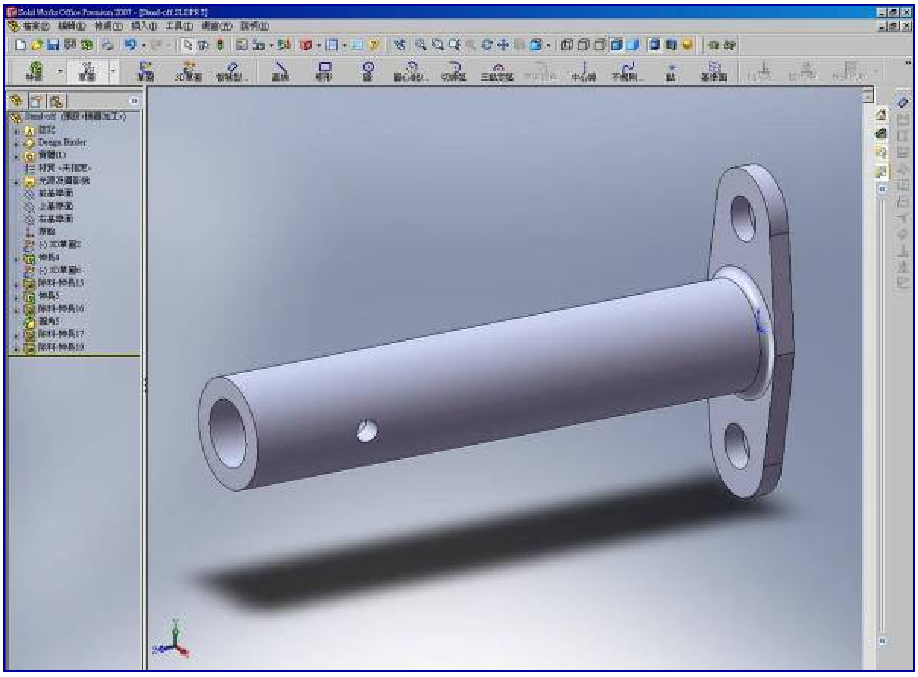
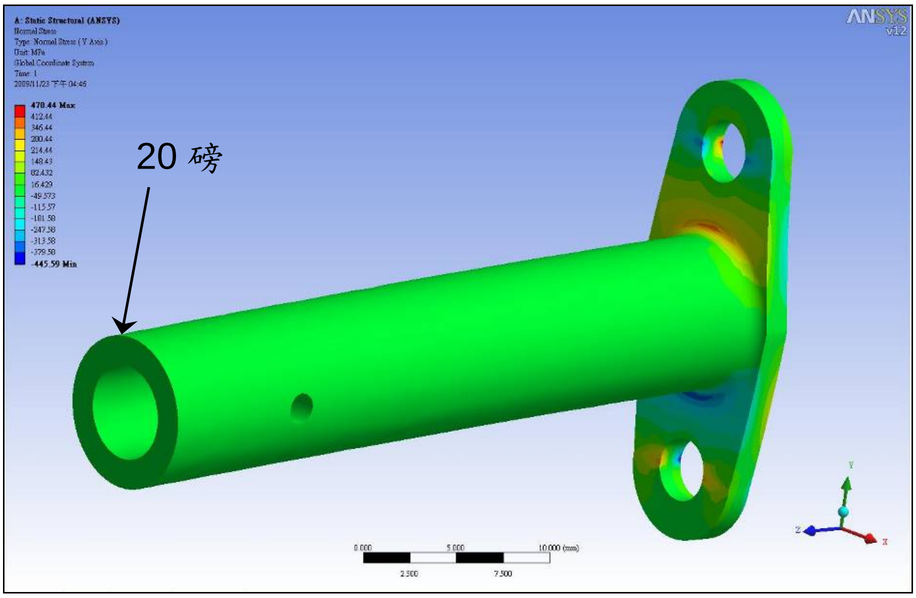


Fig. 2.1-1 the geometric model of standoff



---

load during fracture was unknown.

Fig. 2.1-2 the distribution of principal stress

In order to modify the boundary condition of FEA simulation, a 3D optical scanning technology is conducted to scan and measure the failure standoff, and the geometric model of failure standoff is obtained[9], shown in figure 2.1-3. As specified in Chapter 1.12.2.3, similar case was found on a sister ship register number B-16411 with identical APU power cable standoff installation at STA. 2060, where the standoff was found bent downward with a pulled loose blind rivet at the upper side and the lower blind rivet head clinched, refer to figure 1.12-35. As a result, investigation teams think the blind rivet at the upper side is loose slightly, and plastic deformation is happened in the upper standoff.

According to chapter 1.16.1, some micro-defects are found on the surface B of the upper ear, shown in figure 1.16-6. The boundary condition of FEA simulation is modified, such as the blind rivet at the upper side is loose slightly, some cracks are added on the surface B, and then compute again. The result of FEA simulation shows that the initial fracture happened near surface B, shown in Fig 2.1-4, and is similar to the conclusion of Chung-Shan Institute of Science and Technology (CSIST).

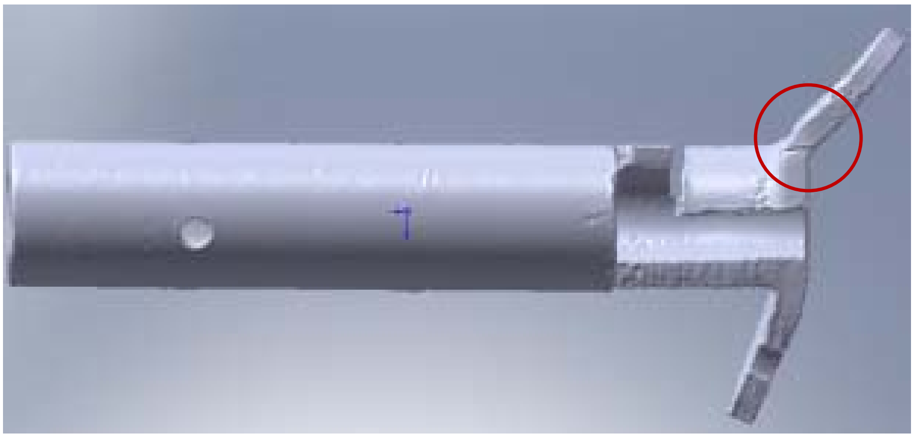


Fig. 2.1-3 a stereo lithography (STL) model of failure standoff

[9] Some part of standoff was sectioned due to material test, and the failure standoff was not intact.

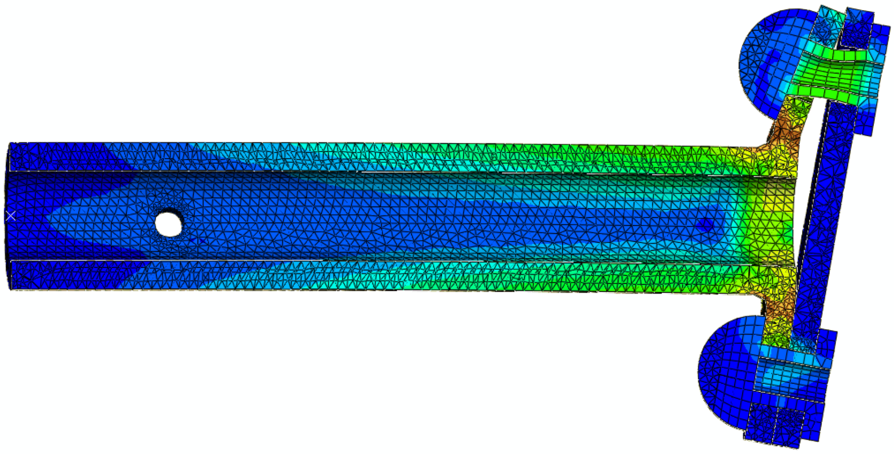


Fig. 2.1-4 the distribution of principal stress of modified simulation

2.1.3 Design of the Standoff

The aircraft, production number RT955, together with two sister ships of the same configuration, production number RM116 and RM117, were equipped with BACN10TL3 aluminum standoff from production line. Other delivered B747-400s prior to June 1997 were equipped with Nylon standoff, service experience revealed breakage and detachment of the nylon standoffs that similar occurrence of arcing were found. Upon this, the design of the standoff was revised by switching the material from nylon to aluminum. A Service Letter, numbered 747-SL-24-060, dated 7th August 2007, was issued to address this arcing issue resulted from the breakage of the nylon standoff, also stated that newly revised standoffs utilizing aluminum material were installed in later aircrafts delivered. In this SL, recommendation was made to operator suggesting replacing the nylon standoffs with the aluminum ones at a convenient maintenance opportunity.

In reviewing the long existing fact that failure of the standoff, regardless made by nylon or aluminum, it is suggested that the excessive load resulted from improper routing and installation of the APU cables, together with the complicate stress condition during aircraft operation, e.g. deformation of the structure, had contributed to the breakage of the standoff. The manufacturer tried strengthen the standoff by changing the material of the standoff from nylon to metal as a solution in overcoming the excessive load, however repeated failure of the aluminum standoff and identical arcing condition thereafter presume that the material selection was not a solution for the root cause of arcing. It is concluded that improper routing and installation of the APU cables and the complicate stress condition during aircraft operation had both contributed to the breakage of the standoff.

Replacement of the material of the standoff, in the view of avoiding the failure of the standoff and resultant arcing is proven insufficient in correcting the excessive loading condition of the standoff from the production line, which is the root cause of the occurrence.

From the Specification of the Standoff P/N: BACN10TL3-18 in Fig 2.1-1, with the shank 1.8 inches long, this 20 lbs load will exert a 36 lb-in torque at the base of the standoff. Observation from section 1.16.1, the fatigue crack is located at the radius intersection of the shank and the base. From these two finding, how the excessive load and the fatigue was related is the key point of strength analysis.

2.2 Fire and Contamination

APU generator feeder cable fell due to the broken aluminum standoff. The fallen cable contacted with the attached bolt of waste tank tube fixture caused worn-out of cable insulation covering. The exposed cable wire contacted with airframe metal parts resulted in a short circuit and arcing which caused the fire of contamination on the insulation blanket. The fire located at the place right below the arcing. Due to the shape of airplane, airframe structure originated from a flat surface and curved toward upward direction gradually. The fire of contamination on the insulation blanket crept upward which resulted in serious fire and subsequent structural damage.

According to Chapter 1.6.6.2, EVA replaced all burned-out insulation blankets from Station 2020 to Station 2060, located at left cabin and lower aft cargo compartment. A large amount of contaminations on the insulation blankets adjacent to the burned-out area were noticed. Those insulation blankets and contaminations were collected and sent to FAA for testing.

According to the test report, a cotton swab burning test was done on two samples without visible contamination. The fires were all extinguished within 8 inches which satisfied the requirement. The same burning cotton swabs were dropped on two contaminated blankets, and the fires extended beyond permitted 8 inches. One of those two tests, sample number 35, used general contaminated blanket and the fire extended up to 9 inches. The other test, sample number 36, used severe contaminated blanket and the fire extended up to half of the up-right surface and the whole flat surface (about 20 inches). The more contaminations on the blanket the larger the area of fire would be.

2.2.1 Sources of Contamination

According to Chap. 1.6.6.1, contamination of insulation blankets, Chap. 1.12.2.1, under floor structure, and Chap. 1.16.2 FAA test results on insulation blankets, the contaminations included CIC, fibers, animal hairs, mineral particles, Styrofoam, metal fragments and insects, etc. CIC contamination on insulation blankets should be due to the application of CIC on structure accidentally during the time maintenance personnel doing structural inspection. Artificial fibers should be from interior furnish such as cloth cover of chair or carpet, and clothes of passengers and crew members. Mineral particles and insects should be from the circulation of air condition system. Animal hairs, Styrofoam and metal fragments should be left from passengers or other personnel.

According to Fig. 1.6-5, when the cycling fans pumped air to the cabin, the pressure of lower cargo compartment will slightly lower than that of cabin. The pressure difference causes air flow from cabin to lower cargo compartment through the DADO panels. Therefore, contamination will be accumulated on the areas below DADO panels. Those heavier contaminations such as animal hair, aluminum foil, carpet fiber and cotton fiber will be accumulated on the blanket. This phenomenon can be confirmed from locally magnified Figures a1, b1 and c1 of Fig. 1.6-6 to Fig. 1.6-8. Those lighter contaminations such as dust particles will flow to the filter of cycling fans. After filtering out contamination, cleaning air is sent back to cabin with the mixture of fresh air.

2.3 Maintenance Operation

2.3.1 Cleaning operation of D Check Maintenance Program

Maintenance operation of the damaged area was scheduled during D Check maintenance. According to Table 1.6-1, the first D Check maintenance was finished on Nov. 27, 2002. After that, EVA modified D Check interval of its 747 fleet from 5 years to 6 years. The transition check was finished on Aug. 24, 2004 in accordance with D Check job cards. The period from the date of transition check to the date of accident is 3 years and 6 months (3.5 years). The fire of the accumulated contaminations already resulted in substantial damage to airplane structure. There still have 2 years and 6 months (2.5 years) to the next D Check. The contamination on insulation blanket will be more serious. From the test results it revealed that the more contaminations the larger the area of fire will be and the more serious damage to airplane will be. Currently, the D Check interval of EVA's 747 airplane is 6 years. The 2.5

years' time interval from the last time D Check was finished to the next D Check will result in serious fire once the insulation blanket is caught fire.

2.3.2 Job Card 1A62IN

From Chapter 1.6.7.3, the contents of task 2 were only aimed at the cleaning operations of insulation blankets that contaminated with dust, lint and trashes etc. There were no procedures to handle insulation blankets that contaminated with CIC.

Furthermore, the note of task 7 only prohibited the application of CIC on the listed areas and components. There were no procedures to handle insulation blankets that contaminated with CIC either. ASC investigators inquired of EVA about the policies when insulation blankets were contaminated with CIC. EVA replied on September 18, 2009:

To handle CIC contaminated insulation blankets, EVA quoted the note from AMM 「NOTE: Do not apply water displacing/anti-corrosion compounds in the following areas: cables, pulleys, wiring, plastics, elastomers, oxygen systems adjacent to tears or holes in insulation blankets interior materials, including cargo liners. APU, APU shroud or any structure in direct contact with the lubricated or Teflon surfaces (e.g. greased joints, sealed bearings) .」 in job card. For example, Para. 7 Note(b)in page 3 of job card 「1A62IN」, and Para. G(1) note in page 5 of job card 「1A34IN」, were the claimed prohibits to contaminated insulation blankets with CIC.

ASC investigators believed that EVA thought its routine cabin cleaning operations and scheduled cleaning programs of those insulation blankets located at cargo compartment could satisfy the suggested requirements of the Service Letters. The established cabin cleaning operations and scheduled cleaning programs were not necessarily to be changed. According to Chapter 1.6.7.2, AMM 25-55-03-404-009, date of revision October 18, 2007, stated that if insulation blankets were contaminated with CIC, oil, wax or liquid stains, they should be replaced. The above statement were revised and incorporated into AMM by Boeing on May 2006. EVA carried out the latest transition check before the accident on August 24, 2004. During that period of time, the statements about the replacement of contaminated insulation blankets were not shown in AMM. According to Chapter 1.18.3, the latest work done to carry out job card 1A62IN was on June 18, 2009. Though this job card was revised, the contents of note of task 7 were the same as those of the job card to which the accident airplane referred during the transition check on August 24, 2004.

AMM is the compulsory reference document to carry out airplane maintenance. The time from the latest work done to carry out job card 1A62IN to the revised date of AMM is about one year and eight months. Job card 1A62IN still has no tasks about inspection and maintenance action on insulation blankets contaminated with CIC. EVA could not take it seriously to incorporate the maintenance actions of CIC contaminated insulation blanket into job card 1A62IN. Maintenance personnel will have no actions at all once they encounter similar condition. As a matter of fact, there were CIC contaminations on insulation blankets in the fire areas of accident airplane. During the application of CIC, maintenance personnel did not take notice of the contamination of CIC on insulation blankets. The CIC contaminated insulation blankets were not removed and replaced during zonal inspection.

2.3.3 EVA's Evaluation on Boeing Service Letters

According to Chapter 1.6.7.1, EVA received those three service letters on April 10, 1998, July 26, 2004 and August 30, 2004 respectively. After receiving those service letters, EVA regarded its routine cabin cleaning operations and scheduled cleaning programs of those insulation blankets located at cargo compartment could satisfy the suggested requirements of the Service Letters. The established cabin cleaning operations and scheduled cleaning programs were not necessarily to be changed. EVA then carried out the works referring to job card 1A62IN on November 27, 2002 and August 24, 2004 respectively. As a matter of fact, airplane accident happened due to large amount of accumulation of contamination and CIC on insulation blankets. These service letters also mentioned CIC contamination caused the accumulation of dust, lint and hairs on insulation blankets located at bilge. Once these areas with a large amount of contamination caught fire, high temperature from fire would result in structure damage. These service letters suggested operators increasing the frequency of cleaning. Pay proper attention to periodic inspection to avoid residues of liquid or oil/wax. Blankets with observable fluids or oily/waxy substances should be removed and replaced with new blankets.

These three service letters stated about the risks, results and suggested actions of insulation blankets contaminated with CIC. The fire areas of the airplane carried out zonal inspection twice, one on November 27, 2002 and the other one on August 24, 2004, before accident. Four years and seven months before the first zonal inspection, Boeing issued Service Letter 747-SL-25-170 to inform operators of the potential fire hazard if CIC contamination was found on insulation blankets. Though the suggestions of the service letter were not mandatory, the fire accident revealed that fire on the contamination resulted in EVA's airplane structural damage. From FAA's test results, the spread of fire exceeded the specified areas of insulation blankets. EVA did not pay proper attention on the evaluation of the received service letters to avoid the occurrence of fire. It is concluded that EVA did not take the CIC and cotton contamination on insulation blankets seriously. The established cabin cleaning operations and scheduled cleaning programs need to be improved.

2.3.4 Maintenance release at Out side Station

Fire and smoke condition of the Insulation blankets was ignited by arcing of the compromised APU power line when the APU was started, the elevated heat from the blanket fire thus tempered the floor beam, stringer, and ventilation truss, resulted in discoloration of the these structure parts.

Upon the fire was extinguished, the EVA out station representative performed visual inspection over the affected area by accessing into the aft cargo hold, assuming that the discoloration, which he was able to remove it by hand, was merely soot from the fire, therefore released this aircraft back to service for the remaining flights without identifying the extend of heat damage to the lower lobe cargo compartment structure, nor did he access and check the upper lobe main deck side wall structure in according to the heat damage verification procedure of the SRM (structure repair manual).

It was until the aircraft returned to the home base in CKS airport that the fire affected area was reopened to be visually inspected and be conducted the continuity test per 747 NDT Part-6, 51-00-00 to verify the extend of heat damage for those discolored structure members. (See Chart 1.12-1 for heat damage summary)

Maintenance personnel at out station, in dealing with such fire and heat damage of the aircraft structure, shall identify the structure integrity of the fire affect area, whether the strength or the material property were compromised or not, either by Continuity Test or Hardness Test per B747-400 Structure Repair manual (SRM) 51-20-02/03, and repair the heat damaged structure to restore the structure integrity before releasing the plane to further flight. From the inspection result in the home base, the floor beam was confirmed damaged from the fire at BKK, revealing that the succeeding revenue flights after the fire were not in compliance with regulation.

2.4 APU Power System

According to Chap. 1.6.4.5, the functions of APU system were monitored and protected by two AGCUs. When differential current of APU supplied power larger than 20±5 amps and exceed 0.04 seconds, current protection will activate APU generator control relay and power breaker to trip generator power supply. The Central Maintenance Computer (CMC) downloaded records were checked. During the flight from Bangkok to Taipei (BR68), a number 1 APU generator intermittent fail message was recorded on ground Bangkok before the date of accident. After the airplane arriving TaoYuan international airport, this number 1 APU was tested by EVA maintenance personnel and the function of APU system was normal. It revealed that the condition of short circuit already existed before the accident. Since the non-flight deck message was only for maintenance reference, the failure condition was not corrected immediately. From the historical record and the trip of APU power of this accident, it revealed that the differential current was larger than the settings of 20±5 amps and exceeding 0.04 seconds which resulted in the activation of circuit protection. The circuit protection activated the AGCR and APB of number 1 APU and tripped the power supply. The short circuit could be disconnected and the arcing of wires could also be stopped. The functions of number 1 AGCU to protect APU generators and power supply was normal during the occurrence.

2.5 Survival Factors

This section we will analyze some topics including abnormal condition notification, smoke source identification, the timing to extinguish fire, Chief purser's action, cooperation and etc. during the smoke observed by passenger until all passengers and cabin crew disembarked.

2.5.1 Identify the fire source and Notification

EVA Air Cabin Crew Handbook[10] section 5.4.2 "*Cabin Fire Fighting Procedures*"[11]：

[10] Version: 2007.03.01 Version8

[11] *A. Source/cause: (1) Identify the likely source/cause of fire. Possible causes are electrical, grease, oil, paper, melting plastic etc.*
B. Type of fire extinguisher: (1) Use the proper extinguisher…
C. Location of the fire: (1) Clear the area surrounding the fire of combustible materials. (2) Remove all oxygen bottles from the vicinity of the fire. (3)Open any cabinets/doors only when ready to discharge extinguishing agent into them ...

According to the above procedures, cabin crew should find out fire source first then judge what kind of possible causes.

The first priority in Cabin Fire Fighting Procedures is to identify the likely source/cause of fire. Because there were no any tools and related training to assist cabin crew discovering the fire source in cargo compartment, the cabin crew of this flight could not immediately identify the fire source.

When this occurrence happened, most of the passengers had stood up from their seats to take their hand luggage and were disembarking on aisle. A passenger in Zone E noticed white smoke to L5 cabin crew. L5 cabin crew immediately went to check and ask other cabin crews to notice Chief Purser and Captain.

EVA Air Cabin Crew Handbook section 5.4.2 "*Cabin Fire Fighting Procedures""Fire fighters actions and crew coordination"：(1)upon discovery of the fire, immediately calls for help, get a proper fire extinguisher and control the fire. Two fire fighters should take turn in control the fire to provide a continuous flow of agent until the fire extinguished; (2) Use a smoke hood and heat resistant glove as necessary ;… (5) The following information should be reported to the Captain and Chief purser: the location of the fire, the present intensity, the possible source of the fire, the condition of the cabin with regards to the present of smoke, the condition of the passengers…*

L5 cabin crew remained on scene to monitor smoke after discovering the smoke, asked other cabin crews reported to the Chief Purser. The Chief Purser immediately noticed to captain. It was compliant with the procedure of cabin crew handbook.

2.5.2 The timing to extinguish fire

To survey EVA Air's training courses regarding the fire fighting, they were found included in the review of Cabin Crew handbook, mock up training with cockpit crew, real practice to fire extinguisher operation (cabin, lavatory and galley) and annual recurrent training. The investigation group found the training program is completely compliant with CAA's requisition.

Because cabin crew could not discover the fire source, the following steps were not executed including to get a proper fire extinguisher and control the fire by using fire extinguisher; use a smoke hood and heat resistant glove; provide a continuous flow of agent.

According to factual information, after ground staff spurt one bottle of fire extinguisher into the side wall, the black smoke then emitted no more. The investigation found if cabin crew immediately execute fire fighting procedure after discovered smoke, it could avoid the large amount of black smoke spreading in cabin.

2.5.3 Decision making to launch the emergency evacuation

The aircraft already taxied to the bridge when the smoke was found. The cabin passengers (Zone A,B,C) had disembarked and the remaining passengers were disembarking. Ground handling was also on progress. According to EVA Air's "Cabin Crew Handbook" section 6.1.1 E[12].

EVA Air's "Cabin Crew Handbook" section 6.1.2 "*Basic Emergency Procedures*"：

A. Captain briefs with Chief Purser and Cabin Crew about the information of the emergency situation.

B. Perform the cabin preparation. (Adjust cabin light to high position.)

C. Cabin Crew takes crew's seat. (Adjust cabin light to Dim/Night position during night flight.)

D. Assume brace position when received Captain's signal.

E. Await evacuation signal.

F. Perform emergency door operation.

G. Guide passengers to evacuate from the aircraft.

H. Check that there is no passenger left in the aircraft.

I. Cabin Crew brings assign emergency equipment and evacuates from the aircraft.

J. Perform the duties after evacuation.

The investigation group found: The occurrence happened during the disembarkation phase with the aircraft already parked in place. Launching the evacuation procedures might en-danger the passengers due to their panic reactions and rushing to the exit doors with limited time to notice the ground

[12] "*After landing, when aircraft has come to a complete stop, it may not be necessary to evacuate the aircraft. Cabin crew must await the Captain's final instructions unless the emergency becomes a life-threatening situation."*

vehicles to leave, in addition, the evacuation might need more time compared to rapid disembarkation from the bridge.

2.5.4 Emergency response

The investigation group reviews the following cabin crew's emergency response in correlated with the passengers' behavior following the occurrence. These included some panic passengers pushed the cabin crew, operated the exit door without cabin crew's permission. The investigation team made the following causes analysis after reviewing:

1. Heavy smoke spreading: The smoke spread rapidly within E zone after the occurrence. Due to the divider curtain closed thus restrain the smoke in curtains, the smoke became heavy in E zone and lowered the visibility to only 8 rows range.
2. The afterward passenger did not fully aware the forward disembarking progress: According to EVA Air's "Cabin Crew Handbook" section 1.1.10 *"After Landing, C. Close class curtain."*, cabin crew from the rear side to the front must report that all passengers have disembarked in their respective area and open the class curtain on normal disembark. This process will regulate the disembark passenger in proper order. However, during the occurrence, E zone passenger witness the smoke became heavy but they did not know whether the forward crew was executing rapid disembarkation due to the closed D,E Zone curtain. Therefore, they questioned the cabin crew' emergency response.
3. The cabin crew' emergency response: After the cabin crews in D,E Zone reported to Chief Purser and Captain, they considered there was no immediate danger and focused on performing door security surveillance to prevent passenger from falling. However, passenger only saw cabin crew's obstructive action, did not know whether the smoke information had passed to commander and had the follow up response. In addition, the cabin crew did not use the public announcement to give the forward passengers rapid disembark instruction.
4. Lack of clear instruction to passenger: According to EVA Air's "Cabin Crew Handbook" section5.4.2 describe: *"Cabin Fire Fighting*

Procedures" E. "Passengers and Crew"：(3) Avoid passenger panic and confusion.[13]

The purpose is to calm the passenger through informing all passengers that the cabin crew already take proper emergency response and keep them in order. There was no clear instruction and information in this flight passing to the passenger during the occurrence.

The Captain assigned the first officer to assist and manage the situation. But the exit path (aisle) was blocked by disembark passenger, hence the first officer and the chief purser were unable to proceed to the occurrence site.

The investigation group found: Panic passenger could be calmed down by proper procedures including using public announcement to inform the E zone abnormal situation and instructing the forward passenger to speed up the disembarkation; opening the class divider curtain to let the smoke propagate evenly and passenger and cabin crew be able to see the entire cabin; using proper wording to calm down the passenger and give self protection instructions(use handkerchief to cover nose and mouth), making public announcement to instruct cabin crew to proceed fire fighting and to assign acting crew to secure the exit doors.

The investigation group also found even though it may not necessary to launch the evacuation, the first officer and the chief purser did not take more active deeds including giving emergency response instructions and speeding up the forward passenger disembarkation while the exit path was blocked by disembarking passenger and unable to proceed to the occurrence site.

2.5.5 Cabin crew cooperation and acting responsibility

According to the reviewing of the factual information, the cabin crew cooperated and worked as a team during the occurrence. For example, L4 and L4' cabin crew came to R5 while the R5 exit door was opened by passenger.

The investigation group found that the cabin crew didn't secure their exit door or re-assign acting crews prior to leave their duty zone to assist other crew member so that the L4 door was not secured by any cabin crew and was opened.

---

[13] *Everything is fine. Please be seated.", "We are extinguishing it now. ", "Please put your head down." , "Please put a handkerchief on your nose and mouth."*

3 Conclusions

In this Chapter, the Safety Council presents the findings derived from the factual information gathered during the investigation and the analysis of the CX521 accident. The findings are presented in three major categories: findings related to probable causes, findings related to risk, and other findings.

The findings related to probable causes identify elements that have been shown to have operated in the accident, or almost certainly operated in the accident. These findings are associated with unsafe acts, unsafe conditions, or safety deficiencies associated with safety significant events that played a major role in the circumstances leading to the accident.

The findings related to risk identify elements of risk that have the potential to degrade aviation safety. Some of the findings in this category identify unsafe acts, unsafe conditions, and safety deficiencies, including organizational and systemic risks that made this accident more likely; however, they cannot be clearly shown to have operated in the accident alone. Further, some of the findings in this category identify risks that are unrelated to this accident, but nonetheless were safety deficiencies that may warrant future safety actions.

Other findings identify elements that have the potential to enhance aviation safety, resolve an issue of controversy, or clarify an issue of unresolved ambiguity. Some of these findings are of general interests that are often included in the ICAO format accident reports for informational, safety awareness, education, and improvement purposes.

3.1 Findings related to probable causes

1. The excessive load resulted from improper routing and installation of the APU cables, together with the complicate stress condition during aircraft's dynamic motion, had contributed to the overload and breakage of the STA 2060 standoff. (2.1.3)

2. The insulation jacket of the detached APU power cable, which had fallen with the failed standoff, then contacted and started chaffing with a tip of a fastener where the cable had landed. Finally the insulation of APU power cable was worn with abrasion which caused the arcing and the fallen sparks ignited the contamination substance on the insulation blankets below. (2.2)

3. A weaker material selection of nylon was not the root cause for the failure of the standoff, the subsequent arcing and the fire. The Service letter 747-SL-24-060 issued on 7^{th} August 2001, proposing an Aluminum standoff in replacing the Nylon ones, is deemed insufficient in resolving the standoff breakage problem. It is concluded that the excessive loading from improper routing and installation of the APU cables and the complicate stress condition during aircraft's dynamic motion operation had both contributed to the breakage of the standoff, which were the vital causes of the occurrence. (2.1.3)

3.2 Findings related to risk

1. According to FAA's test report, a cotton swab burning test was done on two samples without visible contamination. The fires were all extinguished within 8 inches which satisfied the requirement. The same burning cotton swabs were dropped on two contaminated blankets, and the fires extended beyond permitted 8 inches. The more contaminations on the blanket the larger the area of fire would be. (1.16.2)

2. According to Chap. 1.6.7.2, contamination of insulation blankets, Chap. 1.12.2.1, under floor structure, and Chap. 1.16.2 FAA test results on insulation blankets, the contaminations included CIC etc. CIC on the cover film of insulation blanket is capable of collecting animal hairs, lint and cotton fibers than the blanket without CIC contamination. The accumulation of contamination will result in more serious fire. (2.2.1)

3. The period from the date of the last D Check to the date of accident is 3 years and 6 months (3.5 years). The fire of the accumulated contaminations

already resulted in substantial damage to airplane structure. There still have 2 years and 6 months (2.5 years) to the next D Check. The contamination on insulation blankets will be more serious. FAA's test report revealed that the more contaminations the larger the areas of fire will be and the more serious damage to airplane will be. Currently, the D Check interval of EVA's 747 airplane is 6 years. The 2.5 years' time interval from the last time D Check was finished to the next D Check will result in serious fire once the insulation blanket is caught fire. (2.3.1)

4. EVA could not take it seriously to incorporate the maintenance actions of CIC contaminated insulation blanket in accordance with AMM into job card 1A62IN. Maintenance personnel will have no actions at all once they encounter similar condition. (2.3.2)

5. EVA did not pay proper attention on the evaluation of the received service letter 747-SL-25-170-B to avoid the accident. It is revealed that EVA did not take seriously considerations the effects of CIC and cotton contamination on insulation blankets. The present maintenance programs need to be improved. (2.3.3)

6. From the inspection result in the home base, the floor beam was confirmed damaged from the fire at BKK, it revealed that the succeeding revenue flights from BKK to LON then back to CKS after the fire did not have a complete dispatch procedures safety regulations. (2.3.4)

7. Because there were no any tools and related training to assist cabin crew discovering the fire source in cargo, compartment the cabin crew of this flight could not immediately identify the fire source. (2.5.1)

8. Because cabin crew could not discover the fire source, the fire fighting procedures were not executed. (2.5.2)

9. The smoke spread rapidly within E zone after the occurrence. Due to the class divider curtains were not opened, the smoke couldn't propagate evenly and passenger and cabin crew wasn't able to see the entire cabin. Crew did not use public announcement to inform E zone the abnormal situation and to instruct the forward passenger to speed up the disembarkation. Cabin crew did not use proper wording to calm down the passengers and give self protection instructions. Under the above conditions, some panic passengers pushed the cabin crew, operated the exit door without cabin crew's permission. (2.5.4)

10. The cabin crew didn't to secure their exit door or re-assign acting crews prior to leave their duty zone to assist other crew member so that the L4 door was not secured by any cabin crew and was opened. (2.5.5)

3.3 Other findings

1. The thickness measurement results of the straight part and ear part of the standoff are corresponding with the requirement. The material of the sample meets the required 6061-T6 aluminum alloy specification due to the results of the microstructure inspection and micro-hardness tests. (1.16.1)

2. There are fatigue striations characteristics in fracture surface, and ductile dimple-fracture region are found, and the region is supposed to be the final overload fracture. Base on the above analysis, conclusions of CSIST are made as follows: *The cable bracket (standoff) was failed due to fatigue loading effect. It is concluded that the upper ear of the bracket was fracture by excessive fatigue load at the corner, and which subsequently caused the deformation of the lower ear and the loosening of the rivet.* (2.1.1)

3. The standoff carried an extra downward loading of 18 pounds. (1.12.2.1)

4. Contaminations on the insulation blankets included CIC, fibers, animal hairs, mineral particles, Styrofoam, metal fragments and insects, etc. CIC contamination on insulation blankets should be due to the application of CIC on structure accidentally during the time maintenance personnel doing structural inspection. Artificial fibers should be from interior furnish such as cloth cover of chair or carpet, and clothes of passengers and crew members. Mineral particles and insects should be from the circulation of air condition system. Animal hairs, Styrofoam and metal fragments should be left from passengers or other personnel. （2.2.1）

5. The conclusion of the Boeing test report and the component analysis of the insulation blanket surface thin film stated that the insulation blanket cloth was in accordance with the requirement. (1.16.2)

6. Number 1 APU circuit had current difference larger than the setting of 20±5 amps and exceeded more than 0.04 seconds. Circuit protection was activated to trigger AGCR and power breaker APB which interrupted power supply of number 1 APU. The trip of APU power supply prevented power cable from arcing and subsequent fire risk. The function of number 1 AGCU to protect APU generators and power supply was normal during the

occurrence. (2.4)

7. No relevant abnormality was input in the maintenance records. (1.6.8.4)
8. The notification from cabin crew to purser and captain of this flight was compliant with the procedures of cabin crew handbook. (2.5.1)
9. EVA Air's cabin crew fire fighting training program is completely compliant with CAA's requisition. (2.5.2)
10. The occurrence happened during the disembarkation phase with the aircraft already parked in place. Launching the evacuation procedures might en-danger the passengers due to their panic reactions and rushing to the exit doors with limited time to notice the ground vehicles to leave, in addition, the evacuation might need more time compared to rapid disembarkation from the bridge. (2.5.3)

4 Safety Recommendations

4.1 Recommendations

To EVA Air

1. Assessment of the fleet wide condition of the APU power cable installation at BS2060 standoff, including inspection, measurement, and correction of the pre-existing excessive loading if found.
2. In an effort to take account of Boeing's experience and service letter 747-SL-25-170-B, enhancing the evaluation of contamination in the cargo compartment to revise maintenance plan of cabin and cargo compartment accordingly.
3. Review and evaluate job card number 1A62IN and related job cards in accordance with AMM to add inspective and corrective procedures such that maintenance personnel can be complied with.
4. It was not a complete dispatch release to fly from Bangkok to London, Bangkok and Taoyuan. Eva should enhance the outside station maintenance release discipline to eliminate any similar flight to be released for service.
5. To enhance the flight and cabin crew's procedures regarding the fire source identification, fire fighting operation, the timing of using curtain, re-assigning acting crews prior to their leaving their duty zones, leadership, communication, announcement and passenger comforting, especially in the aisle occupied situation. The improved procedures should be put into their related training courses.

To CAA

1. Supervise the operator to assure the mitigation means against the pre-existing excessive loads by assessment/correcting actions of the fleet wide APU power cable installation at BS2060 standoff.
2. Supervise EVA's efforts on the evaluation of contamination in the cargo compartment to revise maintenance plan of cabin and cargo compartment.
3. Supervise EVA's efforts on the evaluation of job card number 1A62IN and related job cards to add inspective and corrective procedures such that maintenance personnel can be complied with.

4. Supervise the operator to ascertain the maintenance discipline and skill level at the out stations will be able to eliminate any substandard and similar flights to be released for service.

5. Supervise the operator to enhance the flight and cabin crew's procedures regarding the fire source identification, fire fighting operation, the timing of using curtain, re-assigning acting crews prior to their leaving their duty zones, leadership, communication, announcement and passenger comforting, especially in the aisle occupied situation. The improved procedures should be put into their related training courses.

To Boeing

1. Develop a solution to eliminate the failure of the STA 2060 standoff which the excessive load had exerted, contributed from the improper routing and installation of the APU cables and the complicate stress condition during aircraft's dynamic motion, had resulted in the breakage of the STA 2060 standoff.

To FAA

1. Supervise the manufacturer to implement a solution to eliminate the failure of the STA 2060 APU power cable standoff which the excessive load resulted from improper routing and installation of the APU cables, together with the complicate stress condition during aircraft's dynamic motion, had contributed to the overload and breakage of the STA 2060 standoff.

APPENDIX

APPENDIX 1 Boeing Service Letter

APPENDIX 2 Passenger Statement of the Occurrence

APPENDIX 3 Test Report of the Standoff from Chung Shan Institute of Science and Technology (Chinese Version Only)

APPENDIX 4 Test Report of the Insulation Blankets from NTSB

APPENDIX 1 Boeing Service Letter

BOEING

Commercial Aviation Services

SERVICE LETTER

SERVICE ENGINEERING • BOEING COMMERCIAL AIRPLANES • P.O. BOX 3707 • SEATTLE • WASHINGTON 98124-2207

707-SL-25-025-B 717-SL-25-105-B
727-SL-25-036-B DC9-SL-25-103-B
737-SL-25-077-B DC10-SL-25-101-B
747-SL-25-170-B MD10-SL-25-101-B
757-SL-25-064-B MD11-SL-25-103-B
767-SL-25-084-B MD80-SL-25-104-B
777-SL-25-018-B MD90-SL-25-102-B

ATA: 2503-00
6 August 2004

SUBJECT: PREVENTING CONTAMINATION THAT AFFECTS FLAMMABILITY OF INSULATION BLANKETS

MODEL: 707/727/737/747/757/767/777/ DC9/DC10 /MD10/MD11/MD80/MD90

APPLICABILITY: All 707/727/737/ 747/757/767/777/DC9/DC10 / MD10 / MD11 / MD80 / MD90 Airplanes

REFERENCES:

a) Multi-Model Service Related Problem (SRP) 25-0103
b) Multi-Model Service Related Problem (SRP) 25-0237
c) 707-FTD-25-04001
d) 727-FTD-25-04001
e) 737-FTD-25-04001
f) 747-400-FTD-25-04003
g) 747-FTD-25-04002
h) 757-FTD-25-04001
i) 767-FTD-25-04001

SUMMARY:

This service letter informs operators of the potential fire hazard if combustible materials (contamination) such as overspray of corrosion inhibiting compound (CIC), hydraulic fluids, oil, pesticides with flammable 'carrier' fluids, grease or dust buildup are allowed to accumulate on the insulation blankets outboard of the passenger/cargo compartment linings. Some types of contaminates have been found to support propagation of flame.

BACKGROUND:

Operators have reported arcing of wires, which result in fire events involving insulation materials. Further evaluation and lab testing of these events has revealed that the presence of corrosion inhibiting compounds (CICs) and other contamination may contribute to the severity of the fire event, and could have been the reason why some fire events were not self-extinguishing. The International Aircraft Materials Fire Test Working Groups (IAMFTWG) "Contamination /Aging" task group, under the leadership of the FAA Technical Center and an ATA member, has conducted investigation and analysis of blankets which has shown an accumulation of various contaminates results in a reduction of flame resistant properties.

DISCUSSION:

Boeing's investigation reference a) (Multi-Model SRP 25-0103) into the CIC contamination also looked at the accumulation of dust, lint and other debris on the insulation blankets in the outboard section of the passenger/cargo compartments. It is conceivable that a large buildup of contaminants on these blankets could ignite as a result of a high temperature source, thereby damaging aircraft structure or systems.

Boeing's investigation of the reference b) (Multi-Model SRP 25-0237) into the effects of aging and contamination on insulation with AN-26 cover film has again determined that contamination bears a large responsibility in the degradation of material ability to prevent flame propagation. More information on the investigation into aging and contamination is contained in references c) through i) FLEET TEAM digest articles. AN-26 cover film was used on Models 707, 727, 737 Classic, 747, 757 and 767 in production.

BOEING ACTION:

The original release of this service letter advised of revisions in the applicable Boeing manuals to address the affects of corrosion inhibiting compound and other materials on the flammability of airplane insulation blankets. The reference a) SRP was initiated to address this issue. Boeing has also presented information on this subject at airline conferences and industry working group meetings to increase operator awareness. Excessive dust, debris, fluids, or overspray of corrosion inhibiting compounds found during any inspection, are considered to be an unsatisfactory condition possibly reducing fire resistance. Cleanup of these materials should be a standard part of maintenance activity. Areas that are more likely to become contaminated are the bilge, the cargo compartment cheeks, and areas outboard of the main cabin sidewalls and air return grills.

SUGGESTED OPERATOR ACTION:

Operators are advised to pay proper increase attention to periodic inspection and cleaning of the airplanes during maintenance to avoid blanket contamination and remove foreign materials. When operators remove linings or otherwise expose insulation blankets, it is suggested that they vacuum loose debris off of the blankets, or use a non-metallic soft brush to remove contamination. Blankets with observable fluids or oily/waxy substances (which typically change the color and appearance of the cover film) should be removed and replaced with new blankets. Boeing does not recommend washing blankets with detergents or solvents to remove contamination, as this can remove flame retardants and leave flammable residue.

Based on their experience, operators can increase the frequency of vacuuming carpet and upholstery to reduce the volume of dirt and fibers in the cabin. Reducing the amounts of dust, dirt, and fibers in the cabin should reduce the amount of accumulated contamination. The use of low lint paper products, and floor mats to clean debris from passenger’s shoes as they enter the airplane may also help to control amounts of contamination brought into the airplane.

WARRANTY INFORMATION:

Warranty remedies are not available for the action suggested by this service letter.

Krijn deJonge
For Respective Fleet Support Chiefs

ABD:vgs

Original — Dated: 23 March 1998

Revision A: — Dated: 25 June 2004. Revised entire service letter. Added cleaning information to suggested operator action and AN-26 data to other sections, removed attached Boeing manual update dates. Also to include Douglas Model Airplanes

Revision B: — Revised to correct Model and Applicability Sections

APPENDIX 2 Passenger Statement of the Occurrence

Fire incident on board BR67 on 23rd February 2008

My Witness account：

Myself, my wife, my four year old son, and my baby daughter, were travelling in the economy cabin in the central bulkhead DEF seats on flight EVA Air's flight BR67 from Taipei to London. We were in, or near, row 61.

Following a rather rough landing at Bangkok, we taxied to the gate (accompanied by the sound of many seatbelts being released by passengers whilst taxiing) and then stopped by the terminal. The aisles were then immediately filled with passengers queuing to get off.

Just a few moments after stopping, there was quite an acrid smell of burning. I looked around, but I could not see any sign of smoke at this point. I commented on the smell to my wife.

A minute or two later, I noticed that some faintly visible smoke was starting to appear a few rows back, around seats ABC. I picked-up my son and said to my wife, who was holding my daughter, that we should take the children further forward.

We made our way in to the aisle but could not move any further forward due to the stationery queue of passengers. I could see that the curtain which divides the economy cabin from the next class was drawn across the aisle, as it would be if everything was normal.

A member of cabin crew headed from the direction of the curtain to the direction of the smoke, where there appeared to be another cabin crew member already. I could not see any cabin crew members manning the curtain at this point.

I then looked back and noticed that the smoke was now much thicker and grey in colour. However, the queue of passengers was still static, the curtain was still closed, and there still did not appear to be any cabin crew making efforts to evacuate passengers from the plane.

I shouted in the direction of the passengers at the front "*Please move forward at the front*". The queue then started to move forward quickly.

A male passenger who had been next to the emergency exit just ahead of me opened the exit. However, the chute did not deploy, and the drop to the ground was substantial. Neither he nor I could see a means of manually deploying the chute.

A few seconds later, the part of the queue where we were was able to start moving forward. However, many passengers behind us were now panicking and pushing from behind. Some came through the galley and my wife and daughter got trapped against the seats. I was forced to physically intervene to free them.

We were then able to briskly walk off through the exit and in to the terminal.

When we got inside, there were EVA groundstaff handing out boarding cards to transfer passengers. I asked them if they were aware that there was an emergency situation, but they were not.

I looked back through the window in the direction of the aircraft, and did not notice any fire appliances.

We then waited to find out what was happening next. Whilst waiting, I spoke to the flight crew that was waiting to board. They were also unaware that there had been an incident prior to my speaking to them. We looked out the window at that point, and incident vehicles and fire appliances were now on the scene.

The next day we were informed by EVA staff that there had been a fire in the cargo bay, that five seats had been damaged as a result, and that the incoming pilot had been aware that something was amiss prior to landing.

We were also advised that in the area where the smoke entered the cabin, most of the passengers were Taiwanese, yet the cabin crew on duty were Thai. Language difficulties meant that communication was an issue.

As of the 15^{th} March, no representatives from EVA have approached us for our accounts of the incident.

My Concerns：

The cabin crew did not appear to take the lead in evacuating the aircraft. This may be due to a lack of assertiveness, evident by the large volume of passengers allowed to release their safety belts whilst taxiing.

The crew that were visible concerned themselves with investigating the cause of the smoke, but this left nobody to man the emergency exits or evacuate passengers quickly through the usual exits.

The dividing curtain was left in place, impeding passengers trying to exit and slowing the evacuation.

The length of time taken to evacuate passengers meant that panic was able to set in amongst those closest to the smoke. No longer able to act calmly, panicking passengers appeared quite capable of crushing others that stood in their way.

The chute at the emergency exit did not deploy automatically, and a means to manually deploy was not obvious. The advice notice on the exit only states that the chute deploys automatically.

Communication with ground crew regarding the situation was slow. I was one of the last passengers to get inside the terminal, yet the groundcrew were unaware that there had been an incident.

If it is correct that the captain was aware that there was a fire in the hold prior to landing then:

- Taxiing to the gate meant that the fire could develop more before passengers were evacuated. It also meant that the plane was close by the terminal, and could put those who were inside the building at risk.
- There did not appear to be any fire appliances in attendance on arrival.
- The cabin crew did not appear to have been informed, as evident by their response.

If it is correct that language problems reduce a cabin crew's effectiveness in an emergency, then the crew should have been organised to reduce the likelihood of a problem, ie: Mandarin speaking crew responsible for the parts of the plane where most mandarin speaking passengers are sat, and Thai speaking crew responsible for the parts of the plane where most Thai speaking passengers are sat.

If there is no systematic attempt to capture witness accounts from passengers, then potential information to assist learning (vital for improving responses and minimising risks in the future) is lost.

I have also reviewed the safety cards since the incident, and any methods of manually deploying the chute are still not clear to me, despite having seen an emergency exit up close and open.

Questions arising：

Why did the cabin crew appear to react so slowly?

Did the cabin crew take the most appropriate action by investigating the source of the smoke, or would immediate evacuation have been better? Although hindsight shows that passengers had sufficient time to evacuate the aircraft from the normal exit, could they have known this at the time?

Why did the chute not deploy? Is this related to the doors being put to 'manual'? If so, is there a mechanism to manually deploy the chute?

At what point did the pilot become aware of the situation? Could he have known that the passengers had sufficient time to evacuate the aircraft from the normal exit at the terminal? If he knew prior to taxiing, did he act appropriately when he took the terminal building?

My suggestions for actions to be considered：

Review staff and training standards, to ensure that crew are capable of being sufficiently assertive and knowledgeable enough to be able to take control in an emergency or when passengers ignore safety instructions.

Always keeping the dividing curtain open on arrival, until the last passenger has got off.

Review processes for alerting others – cabin crew to cabin crew, and cabin crew to ground crew - to an incident on board once the reasons for the apparent failure of the existing processes have been established.

Implementing processes to systematically capture passenger witness reports as soon as possible after an incident.

Give consideration to language abilities when deciding on the most appropriate deployment of cabin crew on each flight.

Improve the clarity of written instructions (both on safety cards and the additional sheets given to those seated by emergency exits) and the notice printed on the exit doors, so that it is clearer. The instructions should be tested on people who have no previous experience of using aeroplane emergency exits.

APPENDIX 3 Test Report of the Standoff from Chung Shan Institute of Science and Technology (Chinese Version Only)

中 山 科 學 研 究 院 材 料 暨 光 電 研 究 所

Materials & Electro-Optics Research Division, Chung Shan Institute of Science and Technology

桃園龍潭郵政 90008-8-5 信箱 P.O. Box 90008-8-5, Lungtan, Taoyuan, Taiwan, R.O.C.

TEL: (03)-4711742, FAX: (03)-4714368

材 料 測 試 報 告 Materials Test Report

編號(No.)：97 專-7-151

頁次(page)：1/9

申請單位名稱和地址 Name and Address of Client 行政院飛航安全委員會/台北縣新店市北新路三段 200 號 11 樓	來文編號 Application No. 無
試樣名稱 Name of Sample 電纜線支撐架	項數／件數 No. of Items/Pieces 1/1
試驗項目 Test Items 成份、金相、硬度、破斷面形態觀察、破損分析	日期 Date Y/M/D 建案 Acceptance 97/05/28 完成 Issue 97/07/09
試驗方法（規範）Test Methods/Specifications ASTM E3-01、E384-06	試驗儀具 Test Instruments EPMA、OM、SEM/EDS、微硬度試驗機

1.前言：

送驗試樣係長榮航空 BR67 班機（編號 B-16410）上之電纜線支撐架（材料為 6061-T6 鋁合金），周圍環境及斷裂狀況如照片一。此支撐架因不明原因斷落（外觀如照片二、三），導致電纜線與鄰近螺栓長期摩擦破損，造成電線短路之意外事件。為追查此試樣的斷裂原因，申請單位委請本組進行試樣的材質分析及斷裂面形態觀察，並研判其斷裂原因。

2.材質分析結果：

2.1 成份分析結果：

取電纜線支撐架試樣截面研磨、抛光後以 EPMA（電子探針顯微分析儀）分析，結果如下：

元素	Mg	Si	Cr	Mn	Fe	Cu	Zn	Ti	Al
Wt%含量	0.81	0.53	0.19	0.03	0.22	0.32	0.02	0.02	Rem.

此支撐架試樣的成份符合要求之 AA6061 鋁合金規格。

2.2 金相分析結果：

如照片二所示，取此支撐架未斷裂的耳部縱向截面作金相觀察，結果如照片四、五，可知此支撐架的耳部係鍛造成形，晶粒大小正常，但在靠近轉角處有一微裂縫。照片六為試樣直管部的縱向金相，與耳部相似，顯微組織正常。

2.3 微硬度試驗結果：

試樣直管部：109—116 HV 100gf（相當於 93—99 HB），試樣耳部：110—116 HV 100gf，二者接近且相當於 6061-T6 鋁合金的硬度。

填寫 Prepared by	審查 Reviewed by	核定 Approved by
連絡電話 Contact Tel.		

※ 注意: Form No.: MTES-T-005-1 Issued: 81/10/15 Revised: 93/09/01

1.本報告僅對送驗試樣負責。
This report only accounts for the sample(s) sent.

2 本報告無核章及日期簽署、或塗改、翻製、影印者無效。
This report is invalid without being stamped and dated, or if obliterated, modified, duplicated in any other way.

3.本報告不得作為任何商業推銷廣告或公告之用。
This report should not be used for any commercial advertisement and public statement.

3.破斷面形態觀察結果：

照片三標示之破斷面用掃描電子顯微鏡(SEM)做破斷面形態觀察，此破斷面全貌如照片七所示，表面形態可概分爲上、下二部份，其中的上方破斷面區域起伏較大，下方區域則相當平坦，如照片八所示。照片九爲照片七之藍框區域破斷面放大的形態，局部可見延性凹窩破裂(ductile dimpled fracture)形態，其較高倍率的形態如照片十，此區域應爲最後強制破壞。

此破斷面下方區域（靠近支撐架的底面）磨損較嚴重，但局部區域有清晰的疲勞紋特徵，如照片十一、十二，研判此區域爲疲勞破壞。

4.破損分析：

4.1 送驗之電纜線支撐架的材質正常，符合要求的 6061-T6 鋁合金規格；管壁和耳部的厚度量測結果均符合藍圖（如申請單附件）要求。

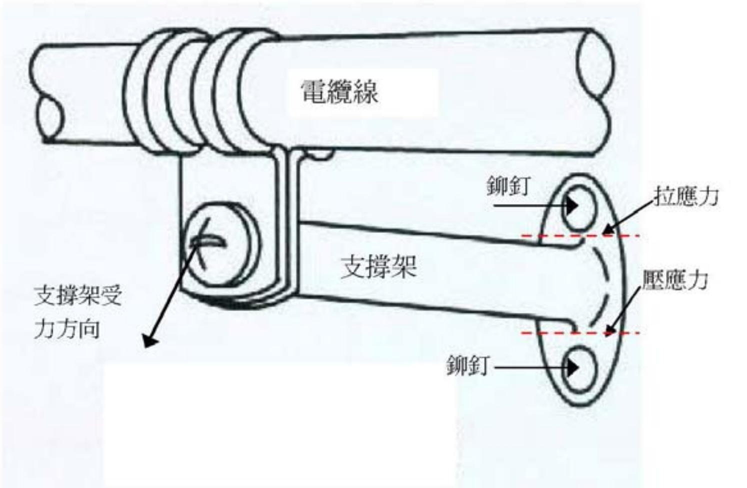
4.2 由此電纜線支撐架斷裂後的狀況（照片一～三），下方未斷的耳部仍附著被拔出之鉚釘，因此研判此支撐架的受力方向如圖一（負荷力向下並有向外拉力），使此支撐架在上方耳部轉角（上方虛線）受到反覆的拉應力（飛行中上下震動所致），並在此位置發生疲勞斷裂，且斷裂起始點係在上方耳部的底面。此支撐架的上方耳部斷裂後，下方耳部因受到過大的拉拔和彎折力而變形及造成下方鉚釘的鬆脫。

4.3 此斷裂之電纜線支撐架（站位：2060）及其相鄰支撐架的相關位置如圖二所示，此位置在電纜線高度升降變化較大處，推判可能受到較大的負荷。

5.結論：

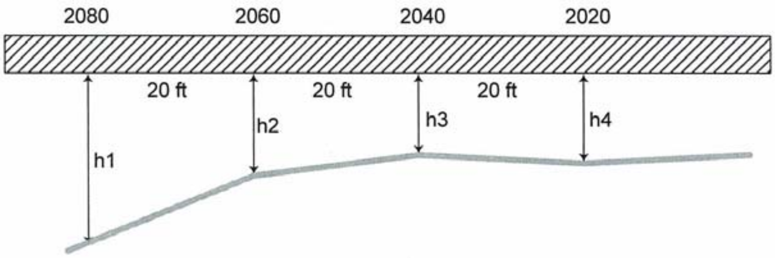
本案的電纜線支撐架試樣係因疲勞負荷作用而發生破壞，研判係上方耳部在支撐架基部轉角處承受過大的疲勞負荷而斷裂，隨後造成下方耳部的變形及鉚釘鬆脫。

--以下空白--



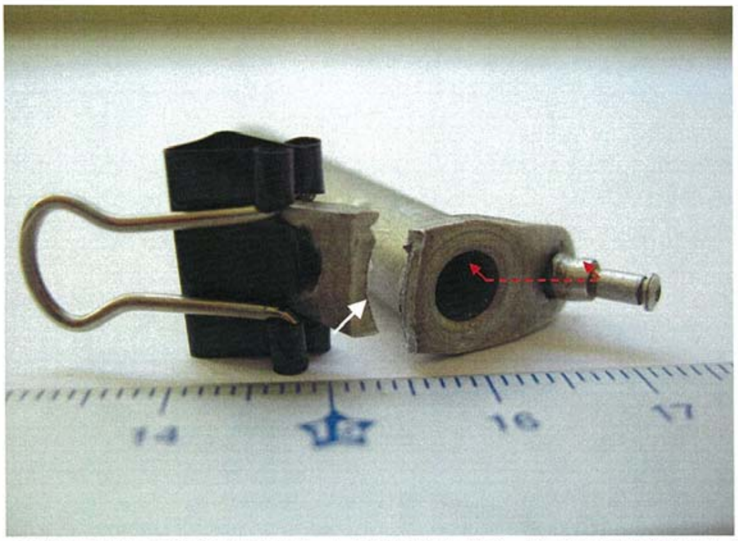
圖一、電纜線支撐架的受力分析圖

站位	2080	2060	2040	2020
距天花板高度	h1	h2	h3	h4
inch	$20\frac{15}{16}$	$12\frac{1}{4}$	10	$11\frac{1}{2}$



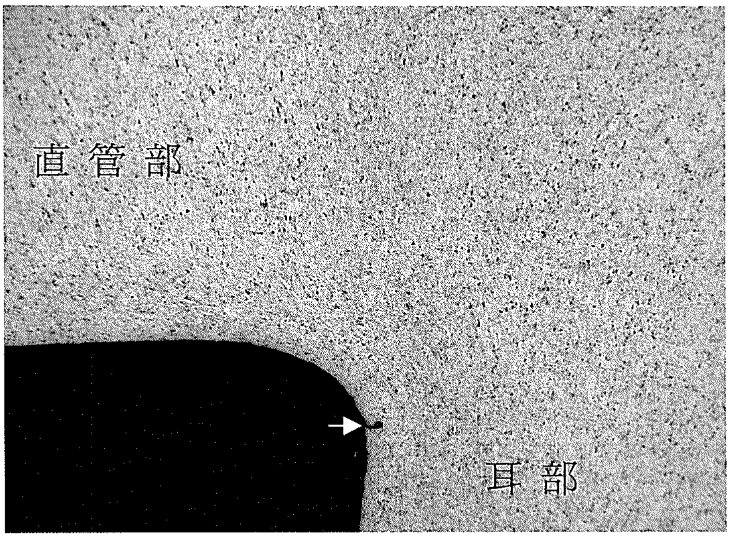
圖二、斷裂之電纜線支撐架（站位：2060）及其相鄰支撐架的相關位置

照片一、斷裂之電纜線支撐架（圈示處）的周圍環境及斷裂狀況



照片二、電纜線支撐架試樣的斷裂情形，白色箭頭處有剪唇。取虛線處的縱截面作金相觀察

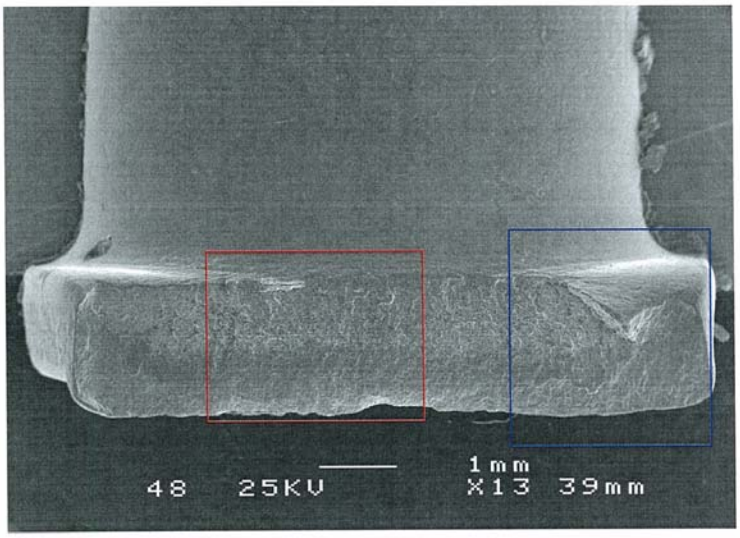
照片三、由另一角度觀察的電纜線支撐架試樣的斷裂情形，箭頭處顯示試樣彎曲



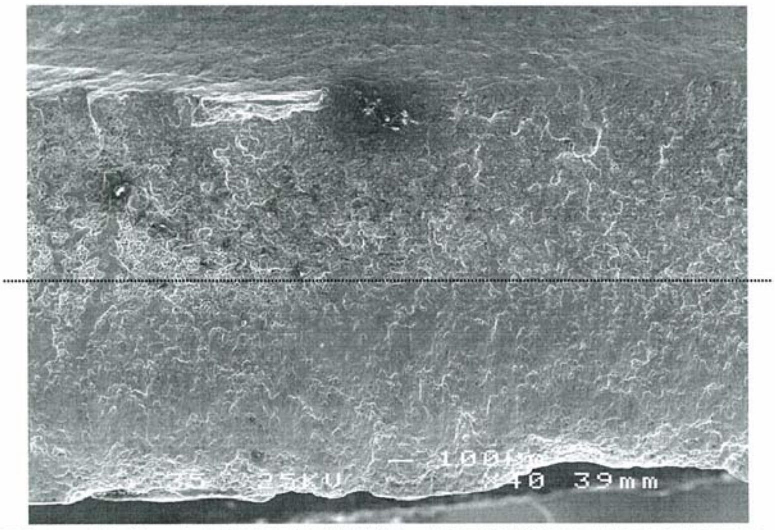
照片四、支撐架試樣轉角處的縱向金相，可知為鍛造成形，箭頭處有微裂（Kroll's reagent, x 50）

照片五、支撐架試樣耳部的縱向金相，晶粒大小正常（Kroll's reagent, x 100）

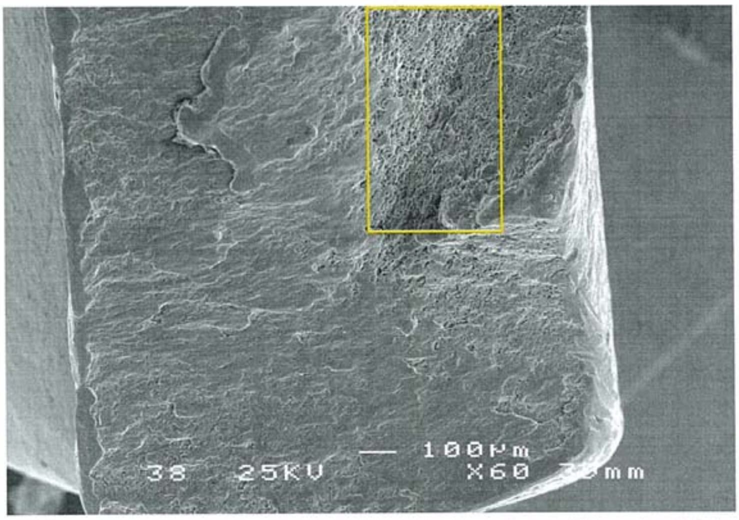
照片六、支撐架試樣直管部的縱向金相，晶粒大小正常（Kroll's reagent, x 100）



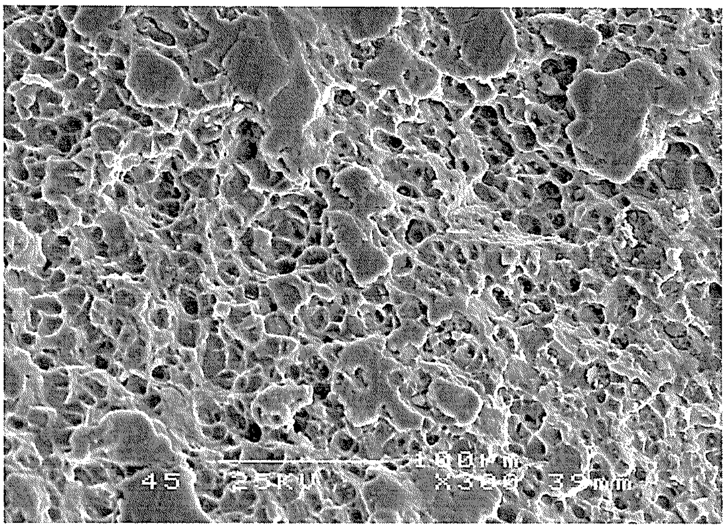
照片七、為照片三之紅框內破斷面的低倍形態（SEM, x 13）



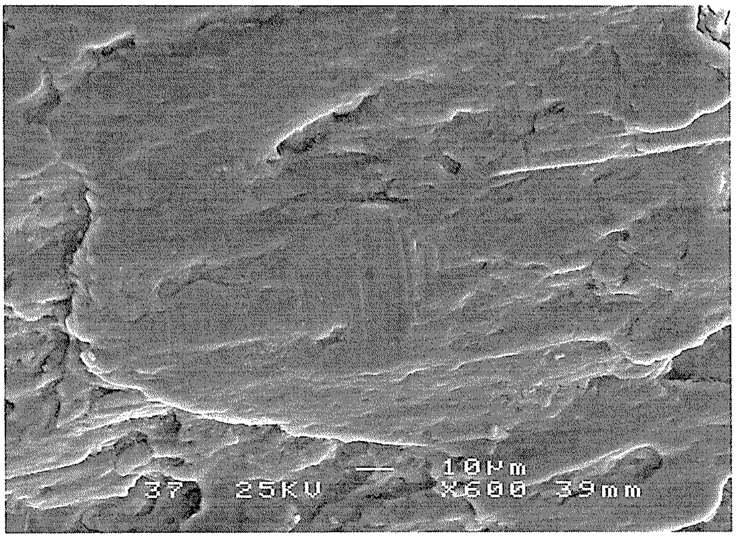
照片八、爲照片七之紅框內破斷面的形態，虛線下方破斷面區域較平坦（SEM, x 40）



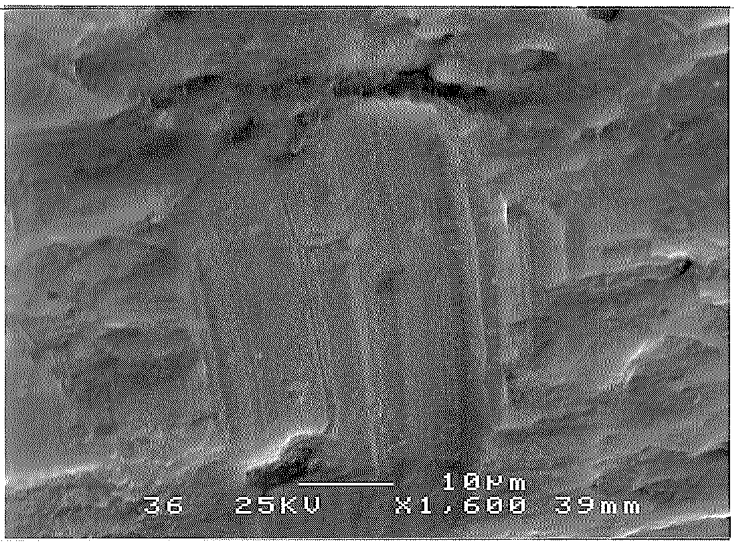
照片九、爲照片七之藍框內破斷面旋轉 90 度後的放大形態，方框區域呈凹窩形態（SEM, x 60）



照片十、為照片九之方框區域表面形態，主要呈凹窩形態（SEM, x 300）



照片十一、為照片七之破斷面下半部的局部形態（SEM, x 600）



照片十二、爲照片十一之中央部份放大的形態（SEM, x 1600）

--以下空白--

中山科學研究院材料暨光電研究所

Materials & Electro-Optics Research Division, Chung Shan Institute of Science and Technology

桃園龍潭郵政 90008-8-5 信箱 P.O. Box 90008-8-5, Lungtan, Taoyuan, Taiwan, R.O.C.

TEL: (03)-4711742, FAX: (03)-4714368

材料測試服務申請單

Application Form for Materials Test Services

來文編號 Application No.：

申請日期 Date (Y/M/D)： 97 年 5 月 28 日

申請單位：行政院飛航安全委員會 Client 地　址：台北縣新店市北新路三段 200 號 11 樓 Address 申請人： Attention	負責人及公司簽章： Client's signature/stamp 電話 Tel.：(02)8912-7388 傳真 Fax：(02) 8912-7398 統一發票編號：16271936 United Code No.
試樣名稱 Name(s) of samples： 電纜線支撐架	數量 Quantity： __1__種 Item __1__件 PCS 測試後試樣處理方式： Sample handling after testing ■ 退還 Return □ 保留 Reserve
委託測試類別 Testing categories： ■ 化學成份 Chemical composition ■ 機械性能 Mechanical properties ■ 顯微組織和缺陷 Microstructure & defects □ 晶體結構 Crystallographic structure □ 熱特性 Thermal analysis	□ 表面與微區成份 Surface & micro- analysis ■ 破損/故障原因 Failure analysis & prevention □ 組件逆向工程 Reverse engineering □ 光/電/磁性 Optical, electrical, magnetic properties □ 材料/光電技術諮詢 Technical consultation □ 其他 Others

試樣編號和背景說明 Sample(s) numbering & background description：

測試需求內容說明，如測試項目、條件、要求規格、分析部位、或注意事項等 Contents of tests：

試樣斷裂原因分析

97. 5. 28

隨附文件 Enclosures：

收件日期 Receiving date：	登錄編號 Registration number：	協辦人 Assisted by： 主辦人 Person in charge：	主 管 Chief：
97. 5. 28 收件章	97專-7-151		

Issued: 81/10/15, Revised: 95/03/01

Form No.: MTES-T-002

※ 雙線以下免填；填妥本表連同試樣郵寄連絡人。

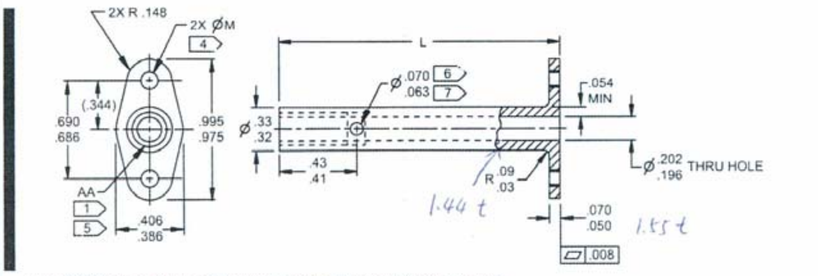
Please fill the spaces above the double-line only and mail the filled form with samples to Miss. Peng or contact her for further information.

******* PSDS GENERATED *******

STATUS OF INACTIVATION
SEE APPLICABILITY BLOCK

BCAG	P	BD&SG	P	BH	P

NEW DESIGN APPROVAL: P=PARTIAL, F=FULL, N=NONE



DIMENSIONING AND TOLERANCING PER ASME Y14.5M–1994.
DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED.

TABLE I

BOEING STANDARD NUMBER BACN10TL	SECOND DASH NUMBER	AA NOMINAL THREAD SIZE UNF–2B PER FED–STD–H28/2 [1]	L ±.02 [2]	ØM [4]	
				INSTALL .0937 SOLID RIVETS "–" CODE	INSTALL BLIND RIVETS "A" CODE
3	3 [3]	.1900–32	.30	.103 .098	.135 .128
	4 [3]		.40		
	6		.60		
	8		.80		
	10		1.00		
	12		1.20		
	14		1.40		
	16		1.60		
	18		1.80		
	20		2.00		
	22		2.20		
	24		2.40		

TECHNICAL CHANGES IDENTIFIED BY REVISION BAR.

DATE 10–MAR–1969 REV (P) 14–FEB–2001

CAGE CODE 81205

BACN10TL SH 1 OF 5

NUT,
SPACER PLATE, LIGHT DUTY

BACN10TL SH 1 OF 5

APPENDIX 4 Test Report of the Insulation Blankets from NTSB

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Aviation Engineering Division
Washington, DC 20594

December 3, 2008

SYSTEMS GROUP FACTUAL REPORT OF INVESTIGATION

A. **ACCIDENT:** ENG08FA028

LOCATIONS: Bangkok International Airport, Thailand

DATE/TIME: February 23, 2008

AIRCRAFT: Eva Air Transportation Boeing 747-400 (BR-16410)

B. GROUP MEMBERS:

Chairman: [redacted]

Member: [redacted]

Member: [redacted]

C. SUMMARY:

On February 23, 2008, a Boeing 747-400 airplane and operating as EVA Air flight BR67 landed at Bangkok.[1] While disembarking at about 1307, passengers from the rear of the cabin noticed smoke coming from the sidewall at seats 64A and65A. Flight attendants suppressed the smoke with a fire extinguisher and the auxiliary power unit (APU) was shut down. Passengers left the airplane by using the forward entrance door to the terminal and no passengers or crew were injured.

The Civil Aviation Administration of Thailand delegated the investigation to the ASC of Taiwan, which was the airplane's nation of registration. Subsequent inspection revealed that an APU generator supply cable had chafed at a cable stand-off and thermal-acoustic insulation blankets from beneath the main deck floor had evidence of fire on the exposed

[1] The airplane was registered as B-16410, Boeing serial number 29061, with 49,000 flight hours and 7,000 takeoff/landing cycles. The fire was at about fuselage station 2060.

interior surfaces. Thermal damage existed on aluminum components near the floor's sidewall vents.

The ASC contacted the National Transportation Safety Board for assistance with investigating the fire on the thermal-acoustic insulation blankets. Participating in support of the NTSB were the Federal Aviation Administration and Boeing Commercial Airplanes.

The research into the thermal acoustic blankets found that each met certification requirements. The research into the contamination on each found wide degrees of variation in flammability, even in a single sample.

D. DETAILS OF THE INVESTIGATION:

Two types of blanket materials were found and varying degrees of contamination were found on each. Samples of the contamination were sent to Boeing for laboratory analysis of what blanket material surface films were involved and to determine what constituted the contamination. Blanket materials from the burned area and new blanket samples made from the current blanket material standards were tested on June 24, 2008, at the Federal Aviation Administration (FAA) fire test laboratory in Atlantic City, New Jersey.

An initial examination showed that the outboard side of the blankets had a non-metalized mylar film surface that was thinner than the thickness of the inner surface. Despite differences in appearance from the yellow and green fiberglass core batting, the surface film was identified by Boeing as polyethylene terephthalate (PET). Boeing examined the contaminates and found localized areas of contamination including mixtures of corrosion inhibiting compounds, synthetic and natural fibers, animal hairs, cellulose fibers, mineral particles, Styrofoam, metal fragments, and insects. (See attached report SR 11299)

The FAA lab tested facial film samples from each side of each blanket and the samples passed vertical strip burn tests. (Reference FAR 25.853, Appendix F) The tests revealed that the skin material of the used blankets could ignite but the spread of flame was slow and would extinguish within the permissible 15 average seconds (3 samples).

Non-regulatory cotton swab burn tests were also performed. The contamination could burn on the surface of the blanket and involve the surface beyond the permissible eight inches. A burning cotton swab was dropped onto a contaminated flat blanket and the burning extinguished. A second burning swab was dropped elsewhere on the same surface and a slowly creeping flame consumed both the surface film and contamination of nearly the entire surface as the flame crept past where the original flame extinguished. (Ref. Figure 1)

Figure 1. An initial alcohol-soaked cotton swab was dropped in the center of the flat area and the flame extinguished. When the flame went out, a small circular hole in the surface film existed in the center of the lower flat area shown. This photo shows a second test, in which a burning alcohol-soaked cotton swab was dropped near the left end of the fold. The visible creeping flame burned around and past where the initial flame stopped when this photo was taken.

APPENDIX 1.

Boeing Material Analysis Report SR 11299

7/22/08 SR 11299 pg 1

To: [redacted]

CC: [redacted]

Subject: Material Analysis of Insulation Blankets from EVA 747-400

ABSTRACT:
Fourteen samples of insulation blanket film from blankets involved in a fire incident on an EVA 747-400 were received by the M&PT Fluids & Lubrication Technology group to:

(1) Characterize the insulation blanket film material
(2) Analyze the surface contamination of the samples

The film material was characterized using Thermo-Nicolet Nexus 670 diamond ATR-FTIR (Attenuated Total Reflectance Fourier Transform Infrared) spectroscopy. Contaminates on the surface of the samples were analyzed using the ATR-FTIR spectroscopy; as well as EPMA (Electron Probe Micro Analysis) to provide elemental data and Polarized Light Microscopy (PLM) to identify particulate matter.

The blanket film material was determined to be consistent with Polyethylene Terephthalate. Additionally surface contamination was characterized as similar to corrosion inhibiting compounds. Particulate matter was identified as synthetic and natural fibers, animal hair, cellulose fibers, mineral particles, plastic, Styrofoam, metal fragments, and insects.

ACKNOWLEDGEMENTS: [redacted]

Prepared by: [redacted]

Approved by: [redacted]

Concurrence by: [redacted]

BACKGROUND:
A fire incident was reported in an EVA 747-400 cargo bay. The insulation blankets from the fire area and near that area were removed. The Flammability, Safety & Airworthiness and Standards Group of M&PT required more information as to the identity of contaminates found on the blankets' surfaces. Sections of insulation blankets involved in the incident and those near by were analyzed to characterize the contamination. The samples were labeled as follows:

1A; 2A; 2B; 3A; 3B; 3C; 3D; 5A;
6A; 6B; 6C; 7A; 7B; 7C

FTIR spectroscopy, EMPA, and PLM were used to identify contaminates and characterize the insulation blanket film. The samples can be seen in Figure 2.

SAMPLE DESCRIPTIONS:
The samples were surface pieces of insulation blanket film. Some samples were heavily contaminated with dust, dirt, fibers, and particulate matter. Also contamination included dried liquids. The samples as received with sampling areas identified can be seen in Figure 2.

RESULTS
Film Characterization:
The exterior surface of the provided blanket film samples were analyzed to confirm the film was Polyethylene Terephthalate (PET) and determine contaminates present. Small sections of the film samples were rinsed with acetone to clean them (where no visible contamination was present). A scalpel was used to cut small pieces of the film out to sample with FTIR. The thermal analysis samples were sized about 1"x1". The blanket film samples were found to be consistent with PET as indicated by presence of characteristic peaks seen in Figure 1 below.

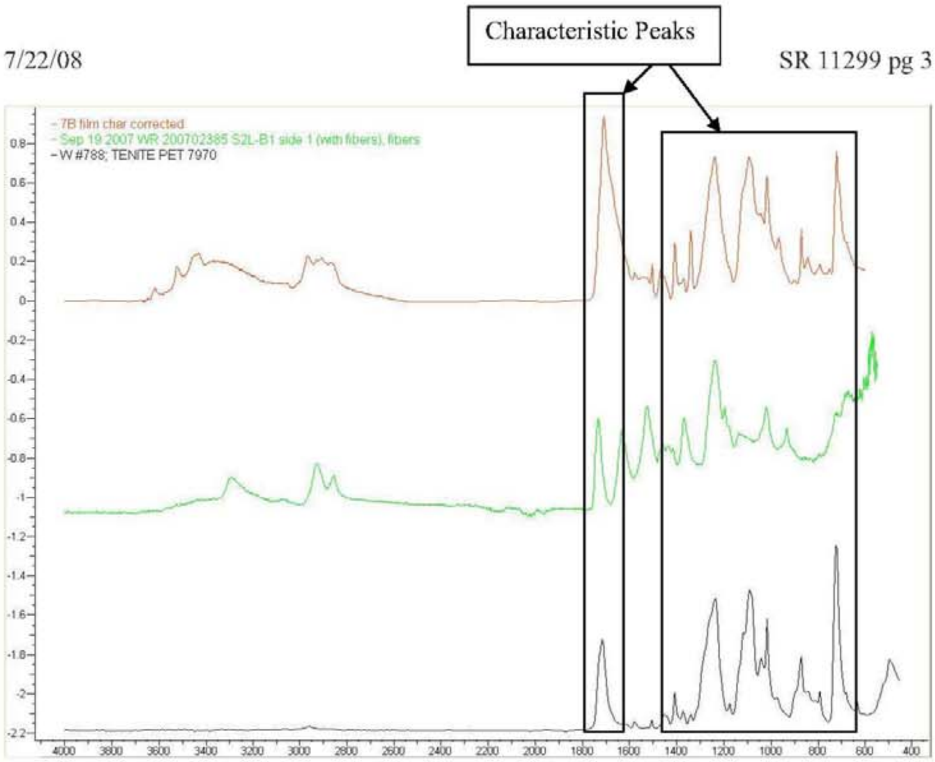


Figure 1: typical spectra of PET (black) compared to spectra of WR200702385 (green) a study of similar insulation blankets and a typical spectra of blanket film from sample 7B (red) showing blanket material is consistent with PET

Surface Contamination Identification:

Sampling areas and techniques can be seen labeled below in Figure 2 and 2A.

On sections of brown contamination the blanket films were rinsed with hexane/ acetone. The solvent was collected and allowed to evaporate. The resulting residue was analyzed with FTIR spectroscopy. In addition, flakes of the dried brown contaminate were removed. The FTIR spectra from both forms of sampling indicated the brown contamination was consistent with corrosion inhibiting compounds as seen in Figures 3 and 4. In addition, EMPA spectra from brown flakes were used, but samples proved to be heavily contaminated by surroundings, a representative spectrum can be seen in Figure 5 and a typical CIC spectrum is shown in Figure 6. Similarities can be seen but are hindered by the amount of contamination.

Figure 2: Films 1-7 Areas of Analysis

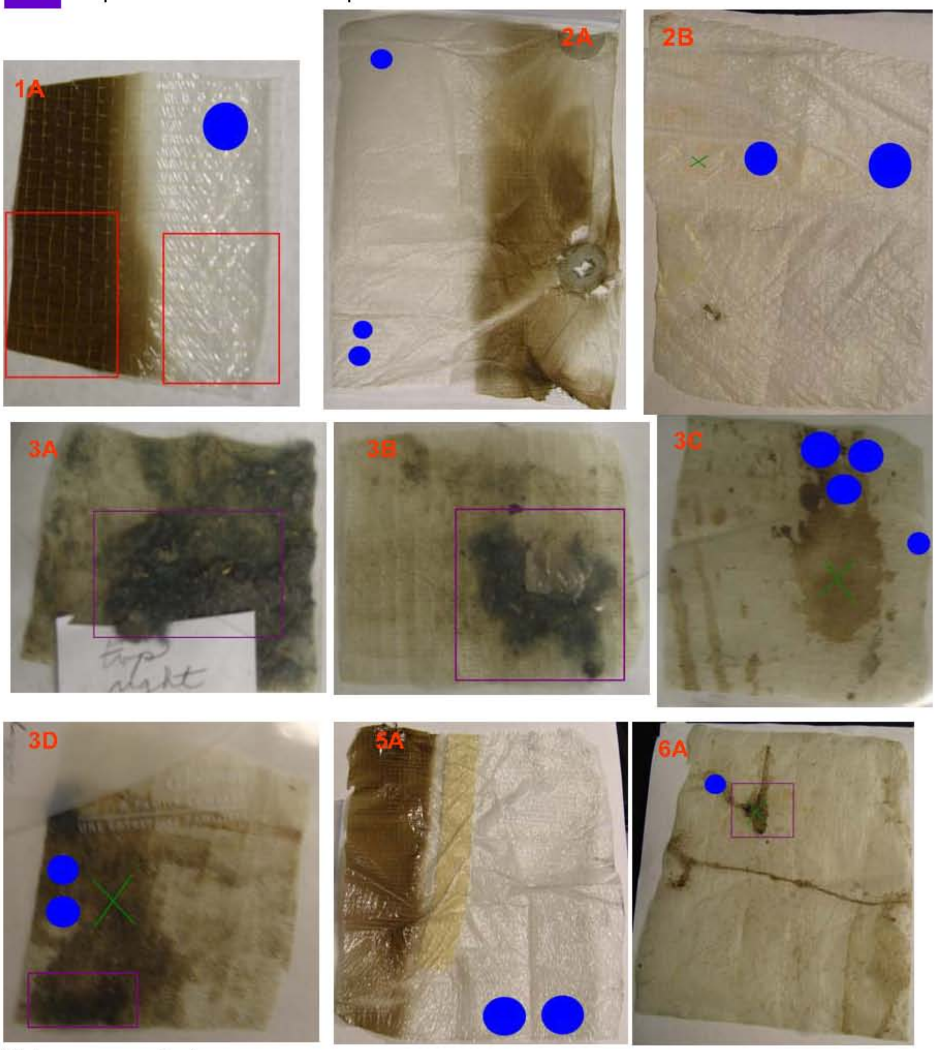
= Thermal analysis TGA

= FTIR analysis

= Microprobe sample

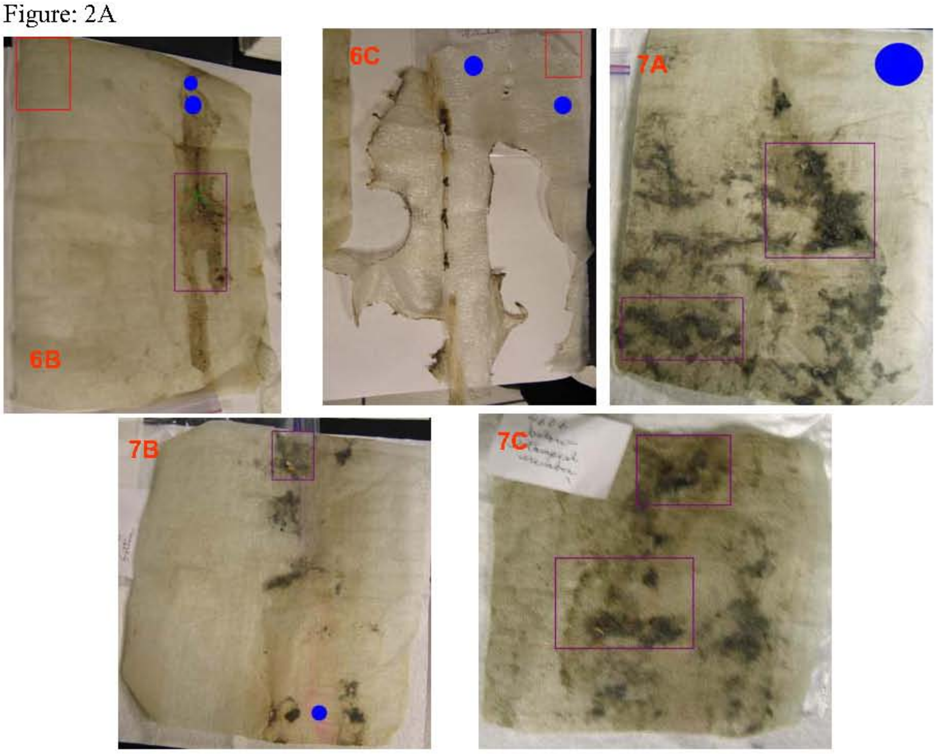
= particulate matter sampled

Part numbers listed in Table I



Note: no sample 4

Figure: 2A



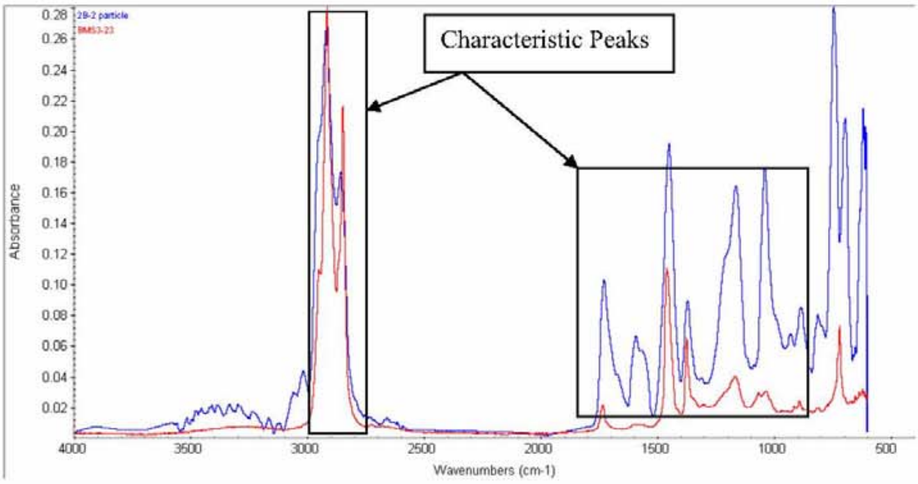


Figure 3: Flake removed from blanket 2B compared to BMS3-23, typical CIC spectra showing flake is consistent with CIC

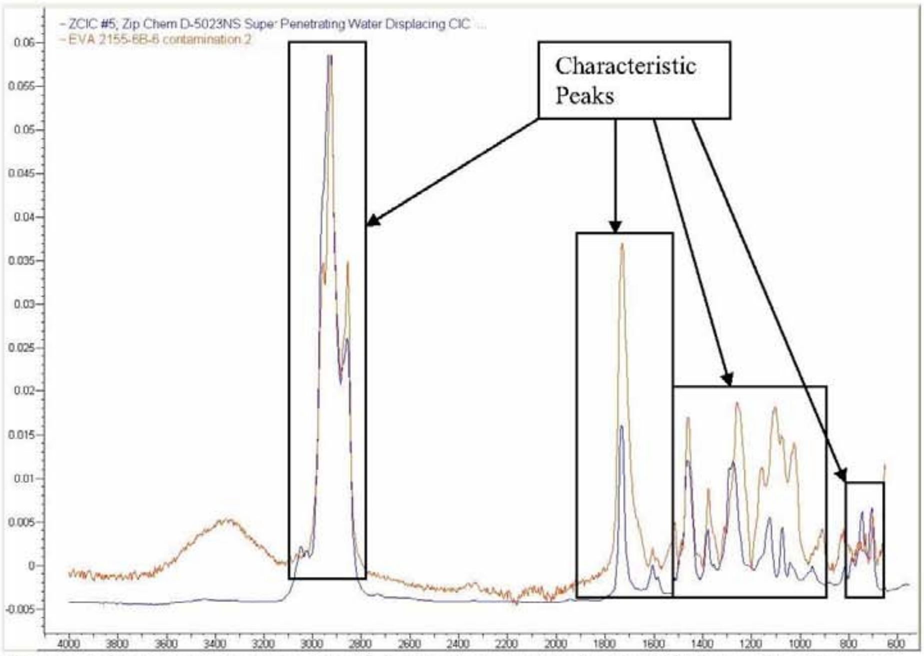


Figure 4: flake sample from blanket 6B compared to typical CIC spectra showing flake is consistent with CIC

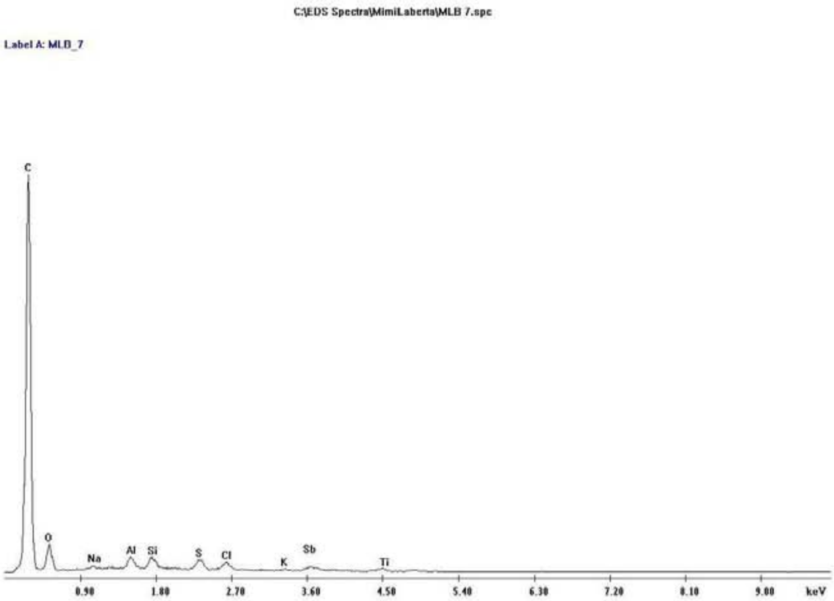


Figure 5: Representative EMPA sample of CIC flake removed from blanket surface

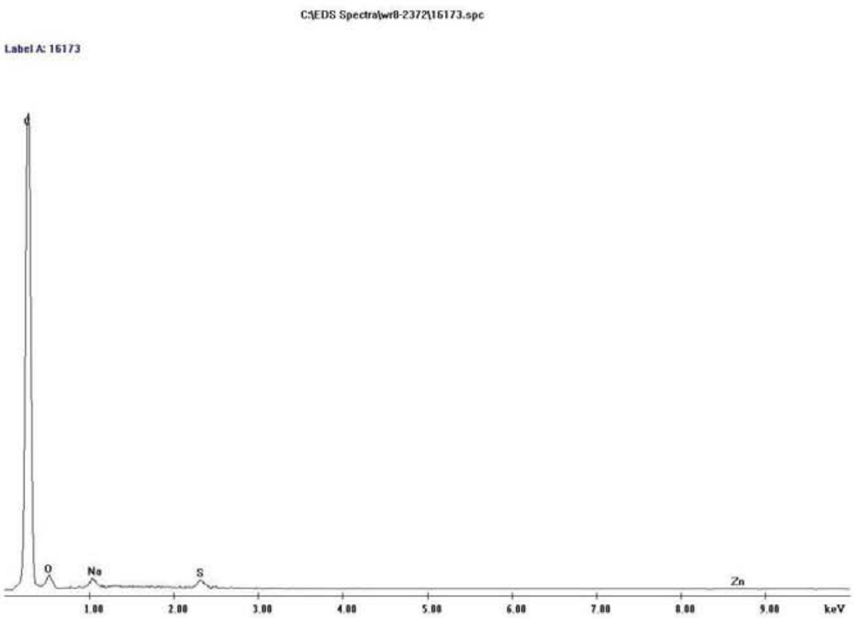


Figure 6: Typical CIC EMPA spectrum

Summary of Results: Table I

Surface Contamination on Insulation Film

Part #	Blanket	Sample	Summary of Results	Thermal Analysis	Microprobe
411U4055-1037	1	1A	film id'ed as PET and areas of thermally damaged PET	√	
		1B	thermally damaged PET		
411U4120-2386	2	2A	film id'ed as PET		
		2B	contamination similar to CIC		√
411U4120-2702	3	3A	see **Table II**		
		3B	see **Table II**		
		3C	film id'ed as PET, contamination similar to CIC		√
		3D	contamination similar to CIC, possible hydraulic fluid		√
61B50025-1002	4		No sample received for this number		
411U4120-2383	5	5A	film id'ed as PET		
411U4120-4302	6	6A	contamination similar to CIC, possible hydraulic fluid		√
		6B	contamination similar to CIC, possible hydraulic fluid	√	√
		6C	film id'ed as PET, contamination similar to CIC	√	
411U4120-4606	7	7A	film id'ed as PET		
		7B	Small area pink contaminate/stain id'ed as dye		
		7C	see **Table II**		

Particulate Contamination:
Particulate contamination was identified by visual inspection using bright field optical microscopy and polarized light microscopy (PLM). Fibrous matter was identified using PLM and index of refraction oils. Fibrous matter was identified as dyed synthetic red, blue, green fibers, dyed cellulose (cotton fibers) and paper like cellulose, also fiberglass similar to blanket insulation and bundles of fiberglass not similar to blanket insulation were found. The particulate matter included: general dust, animal hair (some 4-6" long), cellulose fibers, mineral particles, Styrofoam, metal fragments, insects, and CIC flakes (identified by FTIR and EMPA). Examples of particulate contamination can be seen in Figure 7.

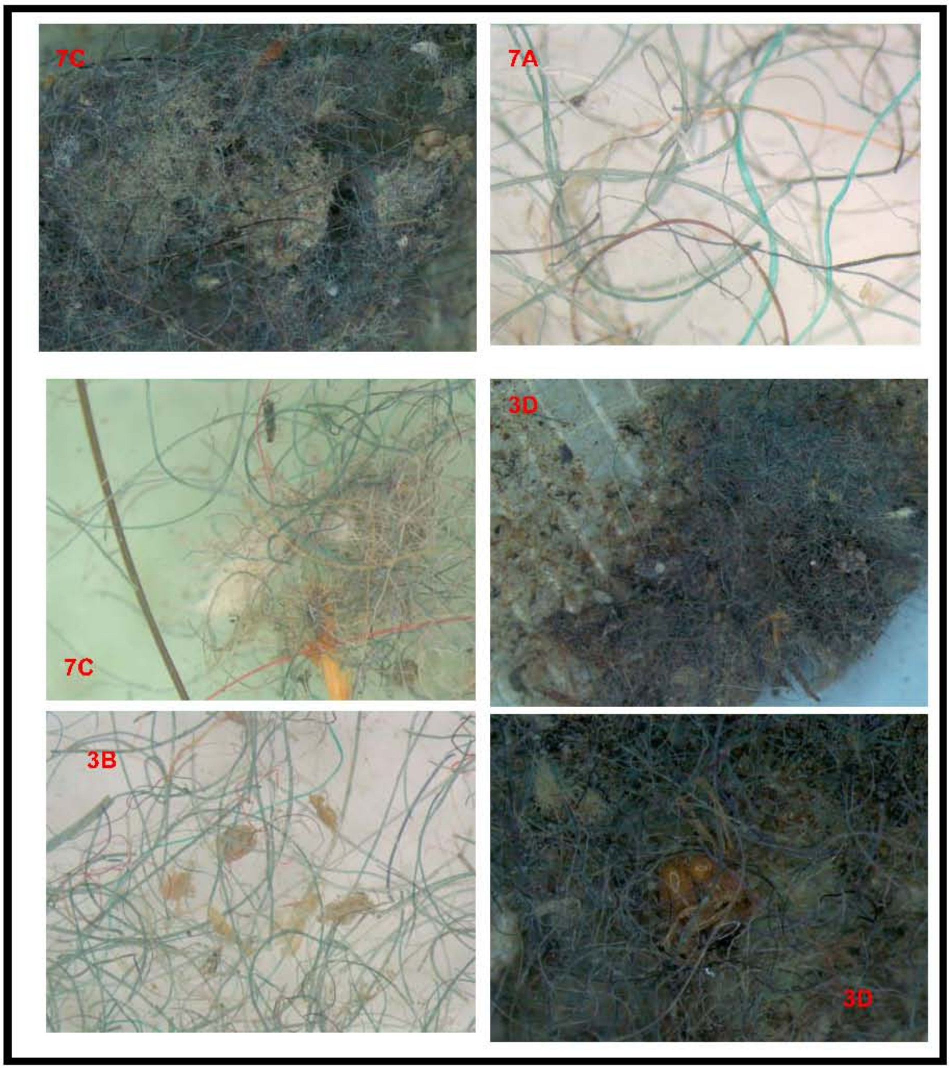


Figure 7: Particulate and Fibrous Particulate and Fibrous Surface Contamination, showing overall view and fibers dispersed view.

Summary of Results: Table II

Particulate Contamination

Part #	Blanket	Sample	Summary of Results
411U4055-1037	1	1A	No obvious particulates
		1B	No obvious particulates
411U4120-2386	2	2A	No obvious particulates
		2B	No obvious particulates
411U4120-2702	3	3A	general dust*, fibers**, animal hair (some 4-6" long) , cellulose fibers, mineral particles, Styrofoam, metal fragments
		3B	general dust, fibers, animal hair, cellulose fibers, mineral particles, plastic, Styrofoam, metal fragments
		3C	general dust, fibers, mineral particles, CIC particles
		3D	general dust, fibers, animal hair, cellulose fibers, mineral particles, CIC particles, insects
61B50025-1002	4		No sample received for this number
411U4120-2383	5	5A	No obvious particulates
411U4120-4302	6	6A	general dust, fibers, mineral particles, CIC particles
		6B	general dust, fibers, mineral particles, CIC particles
		6C	general dust, fibers, mineral particles, CIC particles
411U4120-4606	7	7A	general dust, fibers, animal hair, cellulose fibers, mineral particles, metal fragments
		7B	general dust, fibers, animal hair, cellulose fibers, mineral particles, seed, wood chip
		7C	general dust, fibers, animal hair, cellulose fibers, mineral particles, plastic, piece of sealant

*** Fibers include: dyed synthetic red, blue, green fibers, dyed cellulose (cotton fibers) and paper like cellulose, also fiberglass similar to blanket insulation and bundles of fiberglass**

****General dust includes fine mineral particles, calcium carbonate, calcium sulfonate, and sodium chloride particles**

CONCLUSION:
The insulation blanket film was characterized as similar to Polyethylene Terephthalate reference materials. The surface contamination was consistent with corrosion inhibiting compound. Particulate matter was made up of synthetic and natural fibers, animal hair, cellulose fibers, mineral particles, plastic, Styrofoam, metal fragments, and insects.

References:

a) BMS8-142
b) M&PT Standard Bulletin: Standard Guide for Identification of ORCON Orcofilm® AN-26 and AN-36W Adhesives by Infrared Spectroscopy
c) WR200802155-S00
d) WR200802155-S01

APPENDIX 2.

Data recorded at the FAA Technical Center

The following were the thermal-acoustic insulation blankets tested on June 24, 2008, at the FAA Technical Center fire laboratory:

Blanket #	Part #	Description
1	BMS8-377 Type I & II Class I Orcofilm AN-54W Lot No. 40034	Newly fabricated quilted blanket
2	411U4055-1037 ABN1-12/12/96	Burnt. Green batting
3	411U4120-2386 ABN3-2/22/97	Burnt. Green batting
4	411U4120-2702 ABN1-2/26/96 Mexmil	Severe contamination. Yellow batting. From bulk cargo compartment, left side. BS 1980-2000
5	61B50025-1002 ABN1-2/14/96 Mexmil	From window area. Yellow batting
6	411U4120-2383 ABN3-2/21/97 Mexmil	Almost no contamination. Burnt. Green batting
7	411U4120-4302 Mexmil	Burnt & contaminated. Yellow batting
8	411U4120-4606(?) ABN1-2/26/96 Mexmil	Moderate contamination. Yellow batting. From bulk cargo compartment, left side. BS1960-1980

The insulation blankets had a thick and a thin side with regard to the face sheet. The outboard side was the thin side. The inboard side was the thick side, to resist wear/tearing during maintenance operations. Samples were cut and a small calibrated flame was used to perform 34 vertical strip tests in a flame cabinet (12-second vertical Bunsen burner test). In the cabinet, typical samples had shrinkage, no dripping, and no after-flame.

From 411U4120-2702, one sample had one 23-second time for the flame to extinguish, making it the longest recorded. The average time of the 3 samples was 11 seconds and an average of 15 seconds was permissible, so the blanket did pass.

Tests 35-38 were non-regulatory tests that were performed to examine flame propagation from an ignition source on a representative insulation blanket configuration. The procedure dropped burning alcohol-soaked cotton swabs on sections of blanket that were folded, such that half was vertical and half was flat on the floor. The FAA required the burn damage to not travel more than 8 inches from the initial ignition site. Two of the four blanket samples did not pass this requirement. One of the failures happened after that blanket passed an initial test and was lit a second time at a separate location.

Test #35 used a portion of the –4606 blanket that had a large #8 marked on it. The first swab was dropped on the flat portion of the blanket and the face material shrank for about 3 inches. A second swab was dropped into the crease between the flat and vertical portions, resulting in abut 9 inches of flame travel. The top portion of the blanket folded down and the burning had very little smoke.

Test #36 used a portion of the –2702 blanket that had a heavy layer of contamination. A swab was dropped into the flat portion and the film shrank with little propagation before the flame stopped. A second swab was dropped at the bottom of the heaviest area of contamination on the vertical portion. Small pieces of burning contamination fell to the flat portion, but the flame was stopped at the bottom of the heaviest contamination on the vertical. Almost half of the vertical material was ultimately consumed. The flame continued on the flat portion until most of the facial material was involved by the slowly creeping flame. The group noted that while the blanket passed the first test, the flame from the second swab burned past the area which had passed the requirement, resulting in a failure to pass the requirement during the second test.

Test #37 used a portion of the green –2383 blanket, with a manufacturing date of 2/21/97, and this sample had virtually no visible contamination. The first swab in the center of the flat portion achieved about an inch of facial film shrinkage. The second swab at the crease resulted in film shrinkage of about 3 inches laterally and 5 inches vertically.

Test #38 used a portion of the –2386 blanket that had virtually no visible contamination. The first swab in the center of the flat portion achieved about an inch of facial film shrinkage. The second swab at the crease resulted in film shrinkage of about 7 inches laterally and 6 inches vertically.