DCA FINAL REPORT

REVISION 1

REPORT NO 5135
8 AUGUST 1989
REVISION 1

AIRCRAFT ACCIDENT REPORT

OPERATOR AND OWNER : SOUTH AFRICAN AIRWAYS

AIRCRAFT : **BOEING 747-244B "COMBI" - SERIAL NO. 22171**

NATIONALITY : SOUTH AFRICA

REGISTRATION : ZS-SAS

PLACE OF ACCIDENT : In the Indian Ocean 134 nautical miles North East of Plaisance Airport Mauritius.

DATE OF ACCIDENT : 28 November 1987.

Note : Universal co-ordinated time (UTC) is used in this report.

SYNOPSIS

The State of Registry, Republic of South Africa, (RSA) was notified of the accident by Plaisance Air Traffic Control (Mauritius) at 01:15 on 28 November 1987.

As the accident had occurred outside the territory of any State, the investigation of the accident was conducted by the State of Registry in terms of paragraph 5.3 of Annex 13 to the Convention on International Civil Aviation. This was agreed to by the Government of Mauritius.

The State of Manufacture of the aircraft, United States of America, (USA) was notified of the accident on 30 November 1987 at 08:10 and was requested to participate in the investigation. This State provided an accredited representative from the National Transportation Safety Board (NTSB). The accredited representative was accompanied by representatives of the Federal Aviation Administration (FAA) and Boeing Airplane Company (Boeing). All the representatives had full access to all the phases of the investigation and all the available information. They were very helpful and co-operated fully with the investigator-in-charge.

The operator provided advisors and all possible assistance and logistic support needed in all the phases of the investigation. They also had full access to all available information. Full co-operation was given to the investigator-in-charge.

The representatives of the Operator, Boeing and NTSB undertook to provide the Investigator-in-charge with all the available information which may be required for the investigation of the accident. The Investigator-in-charge provided the factual report to the representatives of the participating parties for information and comments.

The State conducting the investigation (RSA) appointed an accident inquiry board (Board) in terms of Section 12(1) of the Aviation Act 74 of 1962. The Board was comprised of one member from each of the States of Japan, Republic of China, Mauritius, United Kingdom (U.K.), United States of America and three members, including the Chairman, from the RSA.

On 27 November 1987 at 14:23, flight SA 295 departed from Taipei's Chiang Kai Shek Airport for Mauritius' Plaisance Airport with 159 persons on board. Some 46 minutes before the estimated time of arrival at Plaisance the pilot informed approach control that there was smoke in the aeroplane and that an emergency descent to flight level 140 had been initiated. The last radio communication was at 00:04 on 28 No-

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vember 1987. At about 00:07 the aeroplane crashed into the sea.

There were no survivors.

1. FACTUAL INFORMATION

1.1 HISTORY OF THE FLIGHT

On 27 November 1987 flight SA 295 was scheduled to depart from Taipei's Chiang Kai Shek Airport at 13:00 for Mauritius' Plaisance Airport on a scheduled international air transport service (App A P1). Due to adverse weather and the late arrival of a connecting flight the departure time was delayed (App. A p.4) and the aeroplane took off at 14:23 with 149 000 kg of fuel, 43 225 kg of baggage and cargo, 140 passengers and a crew comprising of 5 flight crew members and 14 cabin crew members (App. A p2). The calculated flight time was 10 hours 14 minutes. According to the tape recording of the radio communication with Taipei Approach Control the take-off was normal in all respects. (App A pp 6 - 7). At 14:56:04 the crew communicated with Hong Kong radar and thereafter routine position reports were given to the flight information centres (FIC's) at Hong Kong, Bangkok, Kuala Lumpur, Colombo, Cocos Islands and Mauritius (App A pp8 - 16). At 15:55:18 a routine report was made to the operator's base at Jan Smuts (ZUR). The information given was that the aeroplane had taken off from Taipei at 14:23, was flying at FL 310 and that arrival time at Mauritius was estimated as 00:35. The ZUR radio operator informed flight SA 295 that the selective calling system *(SELCAL) was unserviceable and requested that their next call be at 18:00 (App A p17)

* **SELCAL is a coded system whereby a radio station can call an individual aircraft. The flight crew's attention to a call is drawn by audio and visual means.**

At about 22:30:00 the pilot called Mauritius FIC, using HF radio on frequency 3476 KHz, and advised that they had been at position 070 • East at 22:29:00 at FL 350 and that the time at position 065 • East was estimated as 23:12:00 (app.A p18). At 23:13:27 the position report of 065 • East at FL 350 was given to Mauritius FIC. The estimated time of arrival (ETA) over position 060 • East was given as 23:58:00 (App A p19). As it can be accepted that the aircraft was on track, the position given as 065 • East would have been at latitude 15 • 40' 12" South and position 060 • East at latitude 18 • 57' 54" South (App A p20)

There is no evidence of any distress in the routine HF radio transmissions which ended at 23:14:00.

According to the 30 minute cycle cockpit voice recording which had no time injection, much of the first 28 minutes period was unintelligible, however, sufficient data was recovered to indicate that the conversation was on general topics and did not relate to the aeroplane in any way but 28 minutes 30 seconds after commencement of the recording cycle the smoke warning bell sounded. Somebody, probably the pilot, inquired where it was from and received the reply that it was from the main deck cargo. The pilot then asked that the check list be read. Some 30 seconds later somebody on the flight deck uttered an oath. This word was followed by the CVR 800 Hz test tone on all four channels and ended in a warble at 29 minutes 52 seconds after commencement of the recording. (App A pp21 - 29). It is assumed that the recorded cockpit conversation had commenced very shortly after the HF communication with Mauritius FIC at 23:14:00 and ended shortly before the VHF communication with Mauritius Approach Control at 23:48:51..

According to the Plaisance tower tape recording the pilot called Mauritius approach control at 23:48:51 on 119.1 MHz. At 23:49:07 he said: "Eh good morning we have eh a smoke ehp, eh, problem and we're doing emergency descent to level one five, eh, one four zero". When asked to confirm the descent to FL 140, the pilot said : "Ja, we have already commenced eh, due to a smoke problem in the aeroplane".

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The approach controller gave clearance for the descent and the pilot asked that the fire services be alerted. The controller asked if full emergency services were required to which the pilot replied in the affirmative. At 23:51:02 the approach controller asked the pilot for his actual position. The pilot replied : "Now we have lost a lot of electrics, we haven't got anything on the on the aircraft now." At 23:52:33 the approach controller asked for an ETA at Plaisance and was given the time of 00:30. At 23:52:50 the pilot made an inadvertent transmission when he said to the senior flight engineer: "Hey Joe, shut down the oxygen left". From this time until 00:01:34 there was a period of silence lasting 8 minutes and 44 seconds. From 00:01:34 until 00:02:14 the pilot inadvertently transmitted instructions, apparently to the senior flight engineer, in an excited tone of voice. Most of the phrases are unintelligible. At 00:02:43 the pilot gave a position report as 65 miles. At 00:02:50 the approach controller recleared the flight to FL 50 and at 00:03:00 gave information on the actual weather conditions at Plaisance Airport, which the pilot acknowledged. When the approach controller asked the pilot at 00:03:43 which runway he intended to use he replied one three but was corrected when the controller asked him to confirm one four. At 00:03:56 the controller cleared the flight for a direct approach to the Flic-en-Flac (FF) non directional beacon and requested the pilot to report on approaching FL 50. At 00:04:02 the pilot said : "Kay". (App A pp 30 - 33) From 00:08:00 to 00:30:00 the approach controller called the aircraft numerous times but there was no reply (App. A p36).

The aeroplane crashed into the Indian Ocean at a position determined to be about 19 °10' S and 59 °38' E. The accident occurred at night at about 00:07. This time was determined from 2 damaged wrist watches found in hand baggage. (Photos 1 - 3).

Two persons who were on the south eastern shore of Flat Island, situated approximately 6 nautical miles North of Mauritius, stated that at about the time of the accident they had seen a red and yellow coloured object coming down from an estimated height of 6 to 7 feet above the horizon and disappearing behind Round Island (App A pp 38 - 39). For good reasons it would appear that they had probably seen a meteorite. (App A pp 40 - 41)

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1.2 INJURIES TO PERSONS

INJURIES	CREW	PASSENGERS	OTHERS
FATAL	19	140	nil
SERIOUS	nil	nil	nil
MINOR/ NONE	nil	nil	

1.3 DAMAGE TO THE AIRCRAFT

The aeroplane was totally destroyed. Thousands of wreckage pieces were found scattered on the ocean floor.

1.4 OTHER DAMAGE

There was no other damage.

1.5 PERSONNEL INFORMATION

1.5.1 The pilot-in-command (pilot) was Mr Dawid Jacobus Uys, age 49 years. He held valid and appropriately rated airline transport pilot licence no TA 03896 issued on 18 April 1967. The licence was valid until 4 February 1988 (App. B p1). He was also rated to fly Boeing 707, Boeing 727 and Airbus A300 series aeroplanes. His total flying experience amounted to 13 843 hours of which 3 884 hours were on Boeing 747 series aeroplanes. Flying time during the 90 days preceding the accident was 92 hours, all of which were on Boeing 747 series aeroplanes (App B p2).

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The pilot had a rest period of 79 hours before his duties were commenced on the last flight (App B p2)

According to information supplied by the Institute of Aviation Medicine (App B pp 5 - 11) a skin affliction was reported on 25 January 1979 and was diagnosed as Sezary Cell Syndrome of which the most obvious and important symptom experienced by the pilot, was intense itching. (App B p 14) On 16 February 1979 he was declared temporarily unfit to fly. On 8 June 1979 a medical panel found him physically fit to fly as an airline transport pilot after which time he passed the subsequent medical examinations until 7 July 1987 when a medical panel again declared him temporarily unfit while further examinations were conducted and cortisone treatment was given for a period. (App B p 11). On 18 August 1987 a medical panel decided that he was fit to fly as an airline transport pilot with effect from 18 August 1987 to 5 February 1988, with the following restrictions:

(1) To fly with or as a co-pilot.

(2) Dermatological and blood test reports to be submitted every 6 months (app B p4).

It was felt that the possibility of sudden incapacitation due to the skin condition was extremely improbable . (App. B p 14). All the reports on medical examinations from 25 January 1984 to 12 January 1987 included the restriction that suitable corrective lenses be worn and this restriction was also entered in the pilot's licence.

The pilot's training record (App B pp 16 - 26) was inspected as far back as 1 December 1983. Remarks of "good", "proficient", "satisfactory" and "passed rating" were generaly ma de. On 2 June 1986 and on 4 July 1986 remarks of "Procedures good, passed rating but have organised extra period to polish manual flying" and "Satisfactory test - have pointed out the urgency to keep up to date on handling" were respectively made. Remarks on two route check forms dated 27 May 1986 and 13 March to 21 March 1987 were generally favourable. A remark on the last route check form reads thus : "Capt Uys copes well generally with his flying in spite of his sometimes obvious discomfort due to his skin affliction. This is indeed a credit to him!" (App B p25).

1.5.2 The co-pilot was Mr David Hamilton Attwell, age 36 years. He held valid and appropriately rated airline transport pilot licence no TA 01182 issued on 22 September 1976. The licence was valid until 30 January 1988 (App B p27). He was also rated on Boeing 737-244 and 707 series aeroplanes. His total flying experience amounted to 7 362 hours of which 4 096 hours were on Boeing 747 series aeroplanes. Flying time during the 90 days preceding the accident was 219 hours all of which were on Boeing 747 series aeroplanes (App B p2). His last medical examination was on 20 July 1987 when he was declared fit for 6 months with effect from 31 July 1987 without restrictions (App B p28). Rest period before duties on the last flight was 79 hours. (App B p2).

1.5.3 The third pilot was Mr Geoffrey Birchall, age 37 years. He held valid and appropriately rated airline transport pilot licence no TA 02779 issued on 18 August 1976. The licence was valid until 3 April 1988 (App B p29). He was also rated on Boeing 727 series aeroplanes. His total flying experience amounted to 8 749 hours of which 4 254 hours were on Boeing 747 series aeroplanes. Flying time during the 90 days before the accident was 170 hours all of which were on Boeing 747 series aeroplanes (App B p2). His last medical examination was on 25 September 1987. He was declared fit for six months without restrictions (App B p30). Rest period before duties on the last flight was 79 hours (App B p2).

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1.5.4 The senior flight engineer was Mr Guiseppe Michele Bellagarda, age 45 years. He held valid and appropriately rated flight engineers licence no 209 issued on 27 June 1974. The licence was valid until 22 March 1988 (App B p31). He was also rated on Airbus A300 series aeroplanes. His flying experience as on 30 October 1987 was as follows :

Total : 7 804 hours
Total on Boeing 747 series aeroplanes: 4 555 hours
During 90 days preceding the last flight: 158 hours, all of which were on Boeing 747 series aeroplanes (App B p3)

His last medical examination was on 13 March 1987 when he was declared fit for 12 months (App B p32). Rest period before duties on the last flight was 79 hours. (App B p3)

1.5.5 The second flight engineer was Mr Alan George Daniel, age 34 years. He held valid and appropriately rated flight engineers licence no 389 issued on 8 May 1985. The licence was valid until 21 February 1988 (App B p33). His flying experience as on 30 October 1987 was as follows :

Total: 1 595 hours all of which were on Boeing 747 series aeroplanes.
During 90 days preceding the last flight: 227 hours all of which were on Boeing 747 series aeroplanes (App B p2).

His last medical examination was on 28 January 1987 when he was declared fit for 12 months (App B p34). Rest period before duties on the last flight was 79 hours (App B p2).

1.5.6 The 14 cabin crew members (8 male and 6 female) were trained by the operator. They all received refresher training du-

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ring the course of 1987. Six received practical training in water and in fire emergencies during the period October to November 1987 (App B p35)

1.5.7 An inspection of the operator's training facilities during August 1988 (App B pp 36-47) revealed that not all the requirements of Document LS 101 issued in terms of regulation 14.3(1) of the Air Navigation Regulations, had been complied with during the initial training of cabin crew members (App B pp48-67) e.g. :-

(1) The instructors were not approved by the Commissioner for Civil Aviation.

(2) Initial training arrangements were unsatisfactory such as lack of proper equipment and insufficient training time.

(3) Inadequate practical training on oxygen equipment, fire extinguishing, emergency evacuation and ditching.

(4) Inadequate theoretical training on survival, crowd control and the carriage of dangerous goods.

1.5.8 Prior to the accident the Commissioner for Civil Aviation (CCA) in conjunction with the operator had devised supplementary airworthiness requirements in respect of the training of cabin crew members engaged in public transport operations on aircraft registered in the RSA. These requirements were introduced as from 1 July 1987. As with the introduction of any new system, the requirements were not immediately achievable in their totality. The operator therefore obtained waivers from the CCA on certain aspects. The new requirements were not retroactive and therefore were not ap-

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plicable to the initial training of the cabin crew of flight SA 295.

1.6 AIRCRAFT INFORMATION

The type certification of the aeroplane had been approved on 23 December 1970 under the airworthiness requirements current at that time. The aeroplane was imported into the RSA in November 1980 as a new aircraft. The certificate of airworthiness (C of A) in categories (a),(c), (d),(e) and (f) was issued on 5 December 1980 and was based on the submission of an USA export C of A in accordance with the bilateral agreement between the USA and the RSA (App C p1). No recertification was required nor was any certification data requested or provided. FAA standards were accepted in good faith. The RSA C of A was continuously valid provided that the conditions prescribed thereon were complied with (App C p2)

The aeroplane had flown 26 743,48 hours and completed 4 877 operating cycles since new. It had flown 360 hours since the last Phase A inspection, which was required by the approved maintenance schedule to be carried out at 430 flying hours intervals, and 81 hours since the last terminal inspection which was required at 120 flying hour intervals. (Appendix C pp 3 - 7)

An inspection of the aircraft's maintenance records revealed that it had been maintained in accordance with the requirements of the approved maintenance schedule and the applicable Air Navigation Regulations. There were no known defects when the aircraft departed on the last flight. (App C pp8 - 9). A certificate of safety for flight was issued on 16 October 1987 and was valid for another 70 flying hours, that is until 26 814,09 flying hours had been reached (App C p10).

* Due to the fact that an in-flight fire had occurred in the main deck cargo compartment, special attention has been paid to the maintenance history of the smoke detection system in that compartment.

PREVIOUS FIRE ? CONFIRMED BY SAA TECHNICIAN

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During the periods 11 August to 21 October 1987 and 10 November to 14 November 1987 several defects relating to the main deck cargo compartment smoke detection system were recorded in the on-board technical defect log. Rectification actions included the replacement of no 2B and no 3A smoke detectors and a differential pressure switch (App. C p11). The recovered cockpit voice recording provided conclusive proof that the smoke detection system of the main deck cargo compartment functioned.

The approved Maintenance Schedule prescribes that the orifices in the smoke detection sampling manifolds be inspected for obstructions at every tenth Phase A inspection, i.e. at 4300 hour intervals. Such an inspection was carried out on 2 February 1987 at 24 394 total hours i.e. 2 349 flying hours before the accident. (App C pp 13 - 17).

The aircraft's empty mass and balance was last determined on 23 January 1984 at which time the basic mass empty was 166 129 kg and the centre of gravity (CG) position 34,1226 m (1343,41 inches) aft of the datum. This equals 26.1% of the mean aerodynamic chord (MAC) (App C p11). The structural maximum certificated mass was 377 842 kg for take-off and 285 762 kg for landing. (App C p38).

The aircraft's mass at the time of the accident was calculated as 242 855 kg and the CG position estimated as 28,78% MAC. The CG limits at this mass are 13% and 33% MAC. The aircraft was thus correctly loaded.(App C pp 39 - 43).

The under water inspection of the stabiliser trim actuator jackscrew revealed that 9 screw threads were exposed above the ball nut and 4 threads below the nut. No noticeable bending of the jackscrew had occurred. This suggests that the break may have occurred flush with the ball nut on impact and that the jackscrew may have moved during the break up. The actuator setting as found, equates to a CG position of 27% MAC. If the break had occurred flush with the ball nut the CG position would have been 21,47% if the aeroplane was trimmed for level flight. Both CG positions are within the safe cruising trim range. With all

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159 occupants concentrated in the most forward passenger compartment the CG position would have been 21,5% MAC.(App C pp 41 - 42).

The quantity of aviation turbine fuel in the aircraft at the time of the impact was calculated as approximately 24 370 kg (App C p39).

Of the 43 225 kg of cargo and baggage carried in the aircraft, 14 588 kg of cargo was loaded on 6 pallets in the main deck cargo compartment. This cargo consisted mainly of electrical components and parts, electronic components and parts, hardware, paper articles, textiles, medicines and sports equipment. Some articles from the main deck cargo which were recovered showed evidence of fire damage. None of the observed cargo from the lower holds had any signs of fire or heat.

1.7 METEOROLOGICAL INFORMATION (App D PP 1- 3)

Very little information on the actual weather conditions at the accident site is available. From the actual conditions at Mauritius and Rodriquez together with the 03:00 satellite picture, the following weather conditions were estimated:

Upper wind FL 140 : 160/5-8 kt
Visibility : 10 km or more
Cloud : Scattered cumulus and stratocumulus at 5000 ft

No medium level cloud at FL 140.

The night was dark. The moon had set at 20:16 on 27 November 1987. (App D p4)

S TO NAVIGATION

ie aeroplane was equipped with the following navigational aids and ssociated displays:

3 inertial navigation systems (INS)
2 weather and mapping radars with 300 nm range.
2 radio magnetic indicators (RMI)
1 standby compass
2 automatic direction finders (ADF)
3 very high frequency omni range (VOR) units
3 distance measuring units (DME)
3 instrument landing systems (ILS)

Plaisance Airport was equipped with the following terminal navigational aids:

2 VOR stations
2 DME stations
2 NDB stations

The ground stations were serviceable (App D p5)

1.9 COMMUNICATIONS

The aeroplane was equipped with 2 high frequency (HF) and 3 very high frequency (VHF) transmitter-receiver radio sets. Interphone and passenger address systems were also provided.

The take-off and departure communications with Taipei departure control were normal in all respects (App A pp 6 - 7).

Some 34 minutes after departure from Taipei, SA 295 called Hong Kong Radar at 14:56:04 and obtained direct clearance from ELATO to ISBAN. Normal position reporting was made over ELATO at 15:03:25; SUNEK at 15:53:52; ADMARK at 16:09:54 and SUKAR at 16:34:47 (App A pp 8 -

12). At 15:55:18 a routine report was made to the operator's base station at Jan Smuts (ZUR). The crew was asked to report again at 18:00 as the selective calling system (SELCAL) was unserviceable. The communication with ZUR ended at 15:56:55. The ZUR tape recording ran until about 16:34 (App A p17). As the follow-on tape was apparently later inadvertently re-used, there is no further communication between SA 295 and ZUR on record. The ZUR operator confirmed that there was no other communication. (App E pp1 - 17). The ZUR log shows that at 04:48 on 28 November flight MK 057 had asked the ZUR radio officer when he last had contact with flight SA 295 and was informed "1600 UTC on 27." (App E p28). From 16:49:41 to 21:43:00 position reports were made to Bangkok, Colombo and Cocos. (App A pp 12 - 16). The first HF call to Mauritius on 3476 KHz was made at about 21:46:00 when the crew reported the time at the Mauritius FIR boundary as 21:43:00. At about 22:30 a report of crossing longitude 070 ° East was made (App A p 16). At 23:13:27 a position report of 065 ° East at FL 350 was made to Mauritius (App A p19). From 15:41:06 until 23:14:00 all position reporting was by means of high frequency transmissions. At 23:48:51 the pilot called Mauritius approach control. The following communication was transcribed from the Plaisance control tower tape recording (App A pp 30 - 33). Free translations of Afrikaans phrases are in brackets. Whilst most of the words were clearly recorded and could be easily transcribed, some unintentional transmissions from SA 295 could not be clearly identified as to what was being said.

KEY

295: PILOT-IN-COMMAND OF FLIGHT SA 295

MRU : MAURITIUS APPROACH CONTROL

TIME	SPEAKER	RECORDED INFORMATION
23:48:51	295	Eh, Mauritius, Mauritius, Springbok Two Niner Five
23:49:00	MRU	Springbok Two Nine Five, eh, Mauritius, eh, good morning, eh, go ahead

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23:49:07	295	Eh, good morning, we have, eh, a smoke, ehp, eh, problem and we're doing emergency descent to level one five, eh, one four zero
23:49:18	MRU	Confirm you wish to descend to flight level one four zero
23:49:20	295	Ya, we have already commenced, eh, due to a smoke problem in the aeroplane
23:49:25	MRU	Eh, roger, you are clear to descend immediately to flight level one four zero
23:49:30	295	Roger, we will appreciate if you can alert, eh, fire, ehp, ehp, eh, eh
23:49:40	MRU	Do you wish to, eh, do you request a full emergency?
23:49:48	295	Okay Joe, kan jy ... vir ons (Okay Joe can you ... for us)
23:49:51	MRU	Springbok Two Nine Five, Plaisance
23:49:54	295	Sorry, go ahead
23:49:56	MRU	Do you, eh, request a full emergency please a full emergency?
23:50:00	295	Affirmative, that's Charlie Charlie
23:50:02	MRU	Roger, I declare a full emergency, roger
23:50:04	295	Thank you
23:50:40	MRU	Springbok Two Nine Five, Plaisance
23:50:44	295	Eh, go ahead
23:50:46	MRU	Request your actual position please and your DME distance
23:50:51	295	Eh, we haven't got the DME yet
23:50:55	MRU	Eh, roger and your actual position please.
23:51:00	295	Eh, say again
23:51:02	MRU	Your actual position
23:51:08	295	Now we've lost a lot of electrics, we haven't got anything on the on the aircraft now
23:51:12	MRU	Eh, roger, I declare a full emergency immediately
23:51:15	295	Affirmative
23:51:18	MRU	Roger

23:52:19	MRU	Eh, Springbok Two Nine Five, do you have an Echo Tango Alfa Plaisance please
23:52:30	MRU	Springbok Two Nine Five, Plaisance
23:52:32	295	Ya, Plaisance
23:52:33	MRU	Do you have an Echo Tango Alfa Plaisance please?
23:52:36	295	Ya, eh, zero zero, eh eh eh three zero
23:52:40	MRU	Roger, zero zero three zero, thank you
23:52:50	295	Hey Joe, shut down the oxygen left
23:52:52	MRU	Sorry say again please
00:01:34	295	Unintelligible transmission
00:01:36	295	Unintelligible transmission
00:01:45	295	Unintelligble transmission
00:01:57	295	Unintelligble transmission
00:02:10	295	Unintelligble transmission
00:02:14	295	Unintelligble transmission
00:02:25	295	Carrier wave only
00:02:38	295	Eh Plaisance, Springbok Two Nine Five, do (did) you copy
00:02:41	MRU	Eh negative, Two Nine Five, say again please, say again
00:02:43	295	We're now sixty five miles
00:02:45	MRU	Confirm sixty five miles
00:02:47	295	Ya, affirmative Charlie Charlie
00:02:50	MRU	Eh, Roger, Springbok eh Two Nine Five, eh re you're recleared flight level five zero. Recleared flight level five zero
00:02:58	295	Roger, five zero
00:03:00	MRU	And, Springbok Two Nine Five copy actual weather Plaisance Copy actual weather Plaisance. The wind one one zero degrees zero five knots. The visibility above one zero kilometres. And we have a precipitation in sight to the north. Clouds, five octas one six zero zero, one octa five thousand feet. Temperature is twenty two, two two. And the QNH one zero one eight hectopascals, one zero one eight over

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00:03:28	295	Roger, one zero one eight
00:03:31	MRU	Affirmative, eh and both runways available if you wish
00:03:43	MRU	And two nine five, I request pilots intention
00:03:46	295	Eh we'd like to track in eh, on eh one three
00:03:51	MRU	Confirm runway one four
00:03:54	295	Charlie Charlie
00:03:56	MRU	Affirmative and you're cleared, eh direct to Foxtrot Foxtrot. You report approaching five zero
00:04:02	295	Kay
00:08:00	MRU	Two Nine Five, Plaisance
00:08:11	MRU	Springbok Two Nine Five, Plaisance
00:08:35	MRU	Springbok Two Nine Five Plaisance

(NO ANSWER)

A NTSB human performance expert commented as follows on the pilot's last VHF communication with the approach controller:

"The air traffic recording is generally of very good audio quality. After screening it, I had a definite impression that there were changes in the stress level of the speaker (who was identified to me as the captain) over the course of the tape. From 23:48:51 to 23:49:30) the speaker sounds relatively calm, speaking slowly and courteously (although the seriousness of his communication is clear from its content). At 23:49:30 he fails to complete the sentence, and there is a definite impression that someone or something in the cockpit is distracting him due to the growing emergency. From this point until the end he definitely sounds more agitated, is definitely more distracted, and appears to be talking more quickly. Several of the transmissions, for example form 00:01:34 to 00:02:14, appear to have the high levels of fundamental frequency, speaking rate, and amplitude which are generally characteristic of great psychological stress (the statement at 00:01:45 seems so high it is close to screaming). It should be noted, however, that these statements appear to be inadvertent transmissions meant for the onboard crew and that the speaker may be yelling partly to be heard through his oxygen mask and above the background noise in the cockpit. In the final section, from 00:02:38 to the end, the speaker appears to be more composed and responsive than he was in the preceding section. It seems possible that he has calmed down somewhat and feels that the emergency is more under control at this point than it was at earlier points. These comments are based on simply reviewing the tape and do not reflect scientific measurement for psychological stress". (App A pp 34 - 35).

1.10 AERODROME INFORMATION

The emergency services at Plaisance Airport conformed to category 8 standards as laid down in ICAO's Annex 14 (App D p4). All navigational, landing and communication aids were functioning normally. At 00:25 everything was ready to receive the aircraft in distress and everybody was on alert (App J p2). The aerodrome was not equipped with radar and only runway 14 was equipped with an instrument landing system.

1.11 FLIGHT RECORDERS

The following recorders were fitted :

(1) Penny and Giles quick access recorder (QAR) type D50761 for logging flight data. The QAR was mounted in the main equipment bay just forward of the lower cargo hold at station 460

(2) Lockheed model 209F digital flight data recorder (DFDR) Part no. 10077 A500 - 803 fitted with a Dukane N15F210B underwater locator beacon. The DFDR was mounted on top of a stowage facility in the left hand rear side of the main deck cargo compartment at station 2320.

(3) Collins type 642 C-1 cockpit voice recorder (CVR) Part No. 522 - 4057 -002 fitted with a Dukane N15F210B underwater

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locator beacon. The CVR was mounted next to the DFDR and was the only recorder found and recovered from the sea bed.

After the CVR was found it was handled with great care and all possible precautions were taken to ensure that the recorded information would be retained. To prevent the formation of air bubbles on the tape and hence a deposit of seawater chemicals, the transfer from the lifting tackle to the transport container was performed under the water. Once on board the ship the seawater was replaced with de-ionised water whilst ensuring non-entry of air into the recorder unit. Ice made from de-ionised water was progressivley added to maintain the temperature within the range of 4 to 12 °C. The CVR, in the transport container, was then flown to the operator's suitably equipped laboratory for removal of the tape. All metal tools used for this process were de-magnetised. The tape was removed with the unit submerged in de-ionised water and cleaned in such water by winding it from one reel to another after which it was dried in a vacuum chamber with periodic nitrogen purging. After drying the tape was hand carried to a NTSB laboratory in Washington DC for copying and analysis.

Examination of the recorder revealed impact damage to the outer casing. It had been exposed to heat as evidenced by blistering of the paint. The insulation of electrical wiring found attached to the mounting rack plug was scorched. The solder of some electrical wire joints had melted indicating that the unit had been exposed to heat. The melting point of the solder is between 180 and 190 °C. The interior of the unit was covered with an oily soot, ingress of which was probably through an aperture in the front cover. The plastic blanking plug of this aperture had melted. The signal and control wiring was routed along the top left hand side of the main deck cargo compartment in raceway G and was next to the DFDR wiring. The power supply cable was routed along the top right hand side in raceway H. (App F pp 1 - 4).

The CVR locator beacon was examined by the manufacturer who concluded that the unit had been subjected to external heat in excess of 190° C. This temperature caused the solder around the water switch spring to reflow and hold the switch in the compressed position. This high temperature also damaged the potting compound around the transducer, the transducer itself, and it reflowed solder in the module causing it to short. The electronics module was also found to be internally shorted across the battery connection. (App F pp 5 - 8).

The CVR was powered directly from the essential 115V AC bus and was wired to record from the audio selector panels of the pilot, co-pilot, flight engineer and from the cockpit area microphone. The CVR was not wired for ***"hot mic"** recording but all verbal communications from the abovementioned crew members via oxygen masks, hand held and boom microphones would have been recorded.

***"HOT MIC" recording means that the microphones are connected to a recorder in a manner that ensures the recording of all cockpit sound regardless of audio control panel selections.**

Although the tape was not damaged at all, much of the information which was recorded on the area microphone channel, was unintelligible. Only the last 1 minute and 14 seconds of the 30 minute recording cycle was reasonably clear. However, sufficient data was recovered to determine that the cockpit conversation prior to the sounding of the smoke warning bell had been on general topics only. Joe referred to in the following transcription was the senior flight engineer. Free translations of Afrikaans phrases are in brackets.

TIME IN MINS. AND SECS. FROM BEGINNING OF TAPE	ORIGIN	CONVERSATION/REMARKS
28:31	Fire alarm bell (Stopped almost immediately)	
28:35	Intercom Chime	
28:36	Joe	What's going on now?
28:37	?	Huh?
28:40	Joe	Cargo?
28:42	Joe	It came on now afterwards
28:45		Strong click sound
28:45	?	And where is that?
28:46		Click sound
28:48	Joe (?)	Just to the right
28:49	?	Say again (?)
28:52	Joe	Main deck cargo
28:57	Joe	Then the other one came on as well, I've got two
29:01	Joe	Shall I (get/push) the (bottle/button) over there
29:02	?	Ja (Yes)
29:05	Capt	Lees vir ons die checklist daar hoor (Read the checklist there for us hear) (Double click sound)
29:08	?	Die buik (?) se lig is af (?) (The belly's (?) light is off)
29:09	?	Huh (Two click sounds)
29:11	?	Checklist main deck cargo light
29:12	Capt	Ja (Yes)

		(Sounds of movement can be heard with clicks and clunks)
29:33	Capt	Fok dis die feit dat altwee aangekom het - dit steur mens (Fuck it is the fact that both came on - it distrubs one)
29:36	Intercom chime (While captain is speaking)	
29:38	?	Aag shit
29:40	!!!	(800 Hz TEST TONE signal commences)
29:41	Capt	Wat de donner gaan nou aan? (What the thunder is going on now?) This is said in a surprised tone of voice.
29:44		Sudden loud sound
29:46		Large and rapid changes in amplitude of test tone starts
29:51		End of test signal, very irregular near end
29:52		End of recording. There is about 1 second of old recording on this side of the tape

The 800 Hz test tone is introduced on all four CVR channels. After about 6 seconds rapid changes in amplitude commence. After another 5 seconds the signal ends.

The tape ran for exactly 29 minutes and 52 seconds after its beginning. It was noted that neither the last HF communication with MRU at 23:13:27 nor the first VHF communication with MRU approach control at 23:48:51 was recorded on the CVR.

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1.12 WRECKAGE AND IMPACT INFORMATION

1.12.1 The search for bodies and wreckage was commenced on 30 November 1987 after a decision was made to abandon the search for survivors. Numerous ships, aeroplanes and helicopters took part in the search. From 2 December 1987, the search was concentrated on an accumulation of debris which was drifting in a westerly direction. Spotting was by aeroplane crews who directed the ships to the floating wreckage. Helicopters were used to search the coral reefs for trapped wreckage. The search for floating debris continued in earnest until 10 December 1987.

The floating wreckage consisted mainly of articles of light cargo, cabin panelling, cabin furnishing and escape slides or rafts. It was soon noticed that many of the retrieved articles had been subjected to heat or smoke. Several cargo articles carried in the main deck cargo compartment were burned and some cosmetic panels in the passenger compartment adjoining the main deck cargo compartment were covered with soot. The cabin to main deck cargo compartment door showed signs of heat damage. None of the retrieved articles positively identified as coming from the lower cargo holds, had any signs of exposure to heat or smoke.

On 11 December 1987, 3 ships commenced the search for the underwater locating beacons (pingers) which were fitted to the CVR and to the DFDR. To accomplish this it was essential to set up a grid of navigational beacons. An oceanographic research vessel, which happened to be available at Mauritius, was contracted to do a sonar sea bed survey and to map the sea bed. This survey was conducted from 12 to 21 December 1987 during which time some light pieces of

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debris were seen on the sea bed by means of TV cameras and photographed.

The pinger search continued until 2 January 1988 but without success. Another vessel with special manoeuvring features was hired and then fitted with side scan sonar equipment to search for the wreckage field. Due to unfavourable weather conditions the search could only commence on 25 January. On 28 January the main wreckage field was identified at co-ordinates 19°10' 5" S and 59°36' 57" E at a depth of 4 400m. The debris field position was then marked by the use of two underwater transponder beacons.

The wreckage pieces on the sea bed were found dispersed in two oblong areas with light wreckage some 2,4 kilometres to the North West of the two areas which were displaced in the direction of the normal flight path of 250° magnetic (App G p4).

The longitudinal axes of the two oblong areas were in a general direction of approximately 320° magnetic which is the estimated direction of the ocean current in that region.

The two oblong wreckage areas can be referred to as the North Eastern and South Western areas. The North Eastern area is approximately 1300 m long and 500 m wide while the South Western one is approximately 900 m long and 450 m wide. The centres of the areas are approximately 600 m apart and their perimeters are separated by a zone of some 200 m (App G p 5). Some cargo items, mainly computers, and fragments of wreckage were observed in this area.

The North Eastern area contained debris from aft of No 4 doors and included the following :

Horizontal and vertical stabilizers.
Some 70% of the aft fuselage structure.
The main deck cargo door.
Two sections of main deck cargo floor
No 4B galley
Rear pressure bulkhead.
The auxilliary power unit with its compartment and the tail cone.
Numerous items of main deck cargo. (App G p2).

The South Western area contained the highest concentration of debris from forward of No 4 doors and were extensively fragmented. Major items in this area included three engines, four landing gear assemblies and numerous items of fuselage and wing structures. (App G p2)

The debris in both areas had drifted while sinking. The dispersion of items was influenced by their individual sinking characteristics and the effect of the ocean current. High density items were found in the South Eastern ends of the areas with a progressive spread of items with low sink rates in a down stream (North Western) direction.

After location of the wreckage it was decided to photograph pieces of significance and to retrieve selected pieces. Recovery of the recorders was considered first priority. Photography and recovery of the wreckage were conducted from a specially equipped ship by means of a remotely operated vehicle (ROV).

The photographic and video equipment installed on the ROV also enabled visual inspection of the wreckage. It was therefore possible to identify and inspect many of the wreckage pieces on the sea bed and to decide on recovery priority. Some 3 940 colour photographs were taken and 806 hours of video tape recordings were made. Wreckage pieces of importance were designated target references and numbered in sequence. (App G pp 10-32) It was attempted to retrieve all items of cargo and all wreckage pieces showing evidence of heat but unforeseen circumstances prevented these optimistic intentions. It was however possible to retrieve 25 targets, some of which proved very valuable for investigation purposes. Amongst these were the cockpit voice recorder, rearmost galley support structure, section of main cargo deck fuselage and crown skin and a section of the rear pressure bulkhead.

1.12.2 Examination of the wreckage will be described under four headings, namely :

Recovered floating wreckage.
Wreckage recovered from the sea bed.
Wreckage observed on the sea bed.
Recovered wreckage of which the actual positions in the aeroplane could not be determined.

All the wreckage pieces and items of cargo recoverd are listed at Appendix G pp 33 - 41).

Some wreckage pieces from the passenger cabin and from the main deck cargo compartment as well as articles of cargo carried in this compartment were stained blue. A consignment of blue organic dye powder was carried on the left hand front (PL) pallet.

1.12.2.1 Recovered floating wreckage. (App G pp 43-49).
Examination of the wreckage revealed the following:

(1) Parts of wings secondary structures, such as pieces of access panels, wing leading edges, flaps and ailerons showed

no evidence of smoke or exposure to heat. (App G pp 48-49).

(2) None of the items from the lower cargo hold, the upper deck and from Zones A, B and C of the passenger compartment showed any signs of smoke deposit or exposure to heat except that the portable fire extinguisher from door No 2 right showed soot deposits and splatter of molten material. (App G pp 43 - 45 and 50).

Two rearward facing attendants' folding seats from doors 1 and 2 left were also recovered. The seat at No 1 left hand door was extensively damaged by impact while the seat pan was in the occupied (horizontal) position. The buckle on the right side safety harness was latched and the belt had broken close to the buckle. The harness was found detached from the seat frame. The seat at No 2 left hand door was also extensively damaged, but impact occurred while the seat pan was in the stowed (vertical) position. The safety harness was found unlatched and remained attached to pieces of the seat frame. (App G pp 50 - 51).

(3) The only items from zone D, which showed evidence of exposure to heat and smoke, were two pieces of the right hand life raft stowage bin at body station 1700. Other items such as galley stowage doors at body station 1680, the lower bustle of cabin door No 4 right and the escape slide packboard of cabin door No 4 left showed signs of smoke deposits only. (App G p 52).

(4) A number of items from the main deck cargo compartment (Zone E) showed evidence of exposure to heat and smoke. The partition door between the main deck cargo compartment and the passenger compartment showed heat discolouration on the upper section of the rear lining. This section

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of lining was delaminated from the honeycomb core structure. There was also evidence of blue dye staining and splatter on the inner surface of the aft lining and on the exposed honeycomb structure. The door knob assembly had been ripped out of the door receptacle. The rear door handle adjacent to the knob was adrift at the upper attachment. The retaining collar was missing and the exposed threads showed no signs of smoke deposits. There was some evidence of splatter on the forward decorative lining but no sign of heat or smoke exposure. Part of the upper lining was missing. The door hinge which remained attached to the door support frame showed evidence of smoke streaking and distortion while in the closed position. (App G pp 53 - 55).

The upper bustles of No 5 left and right doors, a shelf from the aft coat closet and a section of left upper side wall lining showed signs of heat damage and smoke deposits. The top section of the left side wall lining showed signs of heat damage and smoke deposits. (App G p 56).

(5) Three slide/rafts and one off-wing slide were recovered. The only observation of possible significance is that damage to the girt bar assembly of the slide/raft identified as from door No 2 left, indicated that this door was probably in the automatic mode. Damage to the girt bar assembly of a slide/raft of which the door number could not be determined, also indicated a probable automatic mode of the door. The position of the third slide/raft was determined as No 4 door left. (App G pp 57-58).

1.12.2.2 Examination of the debris recovered from the sea bed revealed the following:

(1) Section of overhead bin support structure. (Target 213 at App G p 59).

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Evidence of heat and smoke deposits was noticed on the structure extending forward to body station 1320 above the passenger cabin ceiling in zone D. (App G p 60).

(2) Transverse beam structure above galley 4B in Zone E. (Target 214 at App G p 59).

Deposits of molten aluminium, nylon 6.6 with a ball bearing entrapped and a partially melted aluminium bracket with a screw and anchor nut attached, were found on the centre section upper surface of the beam. Insulation of wiring at the rear centre section of the beam was destroyed by heat and showed evidence of arcing. Two of these wires were identified as the 115V AC power leads for the main deck cargo compartment crown lights. (App G pp 61-62).

(3) Section of the forward right main deck cargo floor. (Target 219 at App G p 59).

The floor structure fractured latterally at body stations 1760 and 1960 and longitudinally along the centre line. A piece of fuselage side structure remained attached to the right side which showed evidence of water impact. Molten material and burn marks were evident on the upper surface of the floor between body stations 1760 and 1780. No evidence of heat damage or smoke deposits was noted on the lower surface. (App G p 62).

(4) Piece of the forward left main deck cargo floor. (Part of Target 13E at App G p 59).

The floor section failed at body station 1720 and subsequently at body station 1740 during attempted recovery of target 13E. Deposits of molten aluminium, nylon 6.6 and polyester were evident on the upper surface. No evidence of heat or smoke was observed on the lower surface. (App G p 63).

(5) Section of R/H aft fuselage structure. (Target 197 at App G p 59).
The structure failed at body stations 1720 and 1860 and at stringers 12R and 25R. Heat damage to frames and skin was evident between body stations 1780 and 1840 and stringers 12R and 17R. Heat discolouration of paint occurred on the outer skin surface between body stations 1820 and 1840 and above stringer 17R. Heat damage was apparent on the two lower horizontal straps of the 9G barrier net forward of pallet position PR. The remainder of the horizontal straps above the cabin window level, were burned off either at a position forward of pallet PR or at the fuselage attachment points. (App G pp 63-64).

(6) Section of 9G barrier net with floor mount. (Item L 021).
All vertical straps at body station 1750 and forward of pallet position PR burned off at approximately 1,3 meters above the main deck floor level.

(7) Upper section of galley 4B at body station 1700. (Target 204 at App G p 59).
There was evidence of heat exposure and smoke deposits on the left and right rear top panels and upper surfaces of the galley unit, particularly in the centre and on the right hand side. The unit was relatively intact with some lateral distortion evident on the left. The right side oven doors show evidence of severe frontal water impact damage. (App G pp 64-65).

(8) Large section of lower aft fuselage structure. (Target 244).
No signs of heat exposure or smoke deposits were evident on inner or outer surfaces. The structure showed evidence of water impact damage on the lower right side of the fuselage which is consistent with the impact damage observed on target 219. The lower section of the lower aft cargo door

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was still secured to the fuselage structure by its latches. (App G pp 65-66).

(9) Section of R/H aft fuselage structure. (Target 256 at App G p 59).

The structure fractured at body station 1740 and 2020 and at stringers 4R and 17R. Extensive heat damage occurred to frames and stringers between body station 1760 and 1880 and between stringers 4R and 11R. Smoke deposits and heat discolouration of the paint were evident on the skin surfaces behind some frames and stringers which had become detached from the skin. Eight 9G barrier net straps burned off at their fuselage attachment fittings. Blistering and discolouration of the paint occurred on the outer skin surface between body stations 1800 and 1840 and stringers 4R and 11R. Deformation and buckling of the skin were also evident in this area. This structure matches with targets 197 and 263. (App G pp 66-68).

(10) Section of right hand aft fuselage structure (Target 263 at App G p 59).

The structure fractured at body stations 1940 and 2140 and at stringers 13R and 24R with a small section extending below cabin floor level. Although exposed to the main deck cargo compartment, the insulation blankets in this area provided adequate protection to prevent the formation of smoke deposits. (App G p 68-69).

(11) Piece of R/H aft fuselage structure. (Target 221 at App G p 59).

This piece of fuselage structure fractured at body stations 2120 and 2220 and at stringers 5R and 15R. The structure mates with target 263 at body station 2120 and stringer 15R. Limited heat damage and smoke deposits were evident along the upper section above stringer 7R. (App G p 68).

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(12) Section of aft fuselage crown structure. (Target 255 or 267 at App G p 59).
The structure fractured at body stations 1960 and 2200 and at stringers 5R and 8L. It showed evidence of heavy smoke deposits on the inner surface and heat discolouration of the paint on both the inner and outer surfaces. Deformation of the structure showed a twist in clockwise direction. (App G p 70-71).

(13) Dorsal fin with piece of empennage structure. (Target 38 at App G p 59).
The structure separated at body stations 2200 and 2300 and at stringers 5R and 4L. Paint discolouration, smoke deposits and paint peeling were evident on the inner surfaces at the forward and aft sections of the structure. Blistering of paint occurred on the outer surface. Structural deformation indicated that the dorsal fin had peeled off from the empennage structure in a forward and left direction. (App G p 72).

(14) Life raft support beam at number 5 door position. (Target 130 at App G p 59).
This item showed evidence of slight heat discolouration and heavy smoke deposits on both top and bottom surfaces. Although subjected to heat, the attached electrical wiring insulation remained intact. Only slight structural deformation was evident. (App G p 72).

(15) Passenger entry door, number 5 left. (Target 282 at App G p 59).
The inner surface of the door structure showed evidence of light smoke deposits. The door upper trim bustle (item No 072) showed blistering of the paint due to heat. The door separated from the hinges on impact with only slight damage to the door and its operating mechanism. (App G p 73).

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(16) Two sections of the upper half of the aft pressure bulkhead with elevator cables attached. (Target 39 and 232 at App G p 74).
Heavy smoke deposits and heat discolouration were evident at the top centre sector location and all control cable aperture seals were damaged. There was evidence of light smoke deposits on the aft surface of the bulkhead. (App G pp 73-74).

1.12.2.3 Examination of wreckage observed on the sea bed revealed the following :

(1) Landing gear.
Components associated with the left wing and body gears, the right wing gear and the nose gear, were examined and it was established that the landing gear was retracted at the time of impact. (App G pp 75-76)

(2) Power plants.
The power plants were extensively damaged by impact forces and only three of the four were observed. The nature of damage sustained by the power plants indicated low power, or rotation at the time of impact. (App G pp 77-80).

(3) Large section of left aft fuselage structure incorporating the main deck cargo door. (Target 13E at App G pp 59 and 83-84).
The structure fractured at body stations 1720 and 2000 and extends from below cabin floor level to stringer 1R. Severe heat damage was evident on the fuselage crown structure with signs of smoke deposits extending down to the upper main deck cargo door frame. A large section of the main deck cargo floor is attached to the fuselage structure and deposits of molten material were noted between the 9G barrier net and pallet position PL. Several straps of the 9 G

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barrier net, which were visible, showed some heat damage and signs of blue stains. (App G pp 80-81).

(4) Horizontal stabilizer assembly. (Target 41 at App G p 85). The horizontal stabilizer was found to be complete with elevators attached. There was no evidence of heat or smoke deposits on the skin surfaces. The left stabilizer leading edge was detached from the front spar. The tip and adjacent structure were extensively damaged i.e. split and bent upwards. The outboard elevator tip was detached. It was observed that the stabilizer actuator jackscrew had sheared below the gimbal ball nut with four grooves protruding below the ball nut and nine grooves above. No distortion of the jackscrew was evident. The inboard rib at the root end of the right hand stabilizer leading edge was deformed, indicating an anti-clockwise rotation of the stabilizer assembly when it separated from the aft fuselage structure. (App G pp 81-82).

(5) Vertical stabilizer. (Target 36 at App G p 85). The stabilizer was complete with both upper and lower rudders intact and a section of empennage structure attached to the base. There was no evidence of heat or smoke deposits on the outer surfaces and no significant impact damage was apparent. (App G p 82).

(6) Pallet stack tie down net. Only one net was recovered. The centre portion which covered the pallet stack top had burned away. (App G p 82).

1.12.2.4 Recovered wreckage of which the actual positions in the aeroplane could not be determined. Some of these wreckage pieces showed signs of exposure to heat and smoke. Examples are pieces of cabin ceiling panels and pieces of air ducts.

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1.13. MEDICAL AND PATHOLOGICAL INFORMATION

Fifteen lots of human remains were found and presented for post-mortem examinations. (App H pp 1 - 29). One lot contained the fragmented remains of two different bodies. The lower air passages of one of these two bodies contained soot. (App H p 18). The contents of six lots were only described and not further reported on.

The reports on the medico legal post-mortem examinations on 8 bodies indicated extensive injuries to the upper parts namely to heads, chests and ribs. The causes of deaths of six accident victims were given as multiple injuries and of two as multiple injuries plus carbon monoxide intoxication (App H pp 7 and 21). The blood specimens of these two bodies were in an advanced state of decomposition. The analyses for carboxyhaemoglobin were done by gas chromatography. The carboxyhaemoglobin saturation was 60,5% and 67,2%. No cyanide was found in the blood from the victim that had 67,2% saturation. No mention was made of a cyanide test of the other blood specimen or of any other blood tests. (App H pp30 and 32). The allocated seat numbers of the two victims with high carboxyhaemoglobin saturations were 30E and 40D. The breathing air passages of all eight bodies examined, contained soot. Five of the victims could be identified (App H pp 41-42). They had been allocated seats 30E, 37A, 37D, 40D and 42A (App H p 44).

Radiological examinations were conducted on 5 bodies. No signs of radio opaque foreign objects were found.

1.14 FIRE

1.14.1 The first known indication of fire was an alarm bell recorded on the CVR that was identified by the flight crew as the main deck cargo compartment smoke warning. This occurred 28 minutes 31 seconds from the beginning of the CVR recording. Approximately twenty six seconds later the flight engin-

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eer stated that the "other one came on as well, I've got two". At 29 minutes 5 seconds into the recording the main deck cargo light checklist was called for, and at 29 minutes 52 seconds the recording ended. This was 1 minute 21 seconds after the fire alarm bell was recorded.

At about 23:49 the pilot contacted Mauritius approach control and stated that the flight was in an emergency descent to flight level 140 due to a smoke problem in the aeroplane. Two minutes later, in response to Mauritius' request for a position report, the pilot stated "Now we've lost a lot of electrics, we haven't got anything on the on the aircraft now". About nine minutes later, at 00:02:25 the pilot reported and confirmed "We are now sixty five miles". the flight was recleared to FL50, which was acknowledged by the pilot. In the last series of communications with Mauritius, the pilot requested runway 14 and in the last contact with Mauritius acknowledged an instruction to report approaching FL50. There was no mention of smoke or fire by the flight crew during these last series of transmissions.

1.14.2 Examination of the aeroplane wreckage disclosed heat and smoke damage that was most prominent in the main deck cargo compartment, consistent with the alarm recorded on the CVR. However, some heat and smoke damage was found in the aft galley area, which is forward of the partition that separates the passenger cabin from the main deck cargo compartment. Additionally, lethal levels of carboxyhaemoglobin were found in the blood of two passengers from which suitable specimens were obtained. Soot deposits were present in the respiratory tracts of the eight passengers that could be examined. It was noted that the area of greatest concentration of structural damage due to heat was in the upper area of the fuselage in the right front portion of the main deck cargo compartment.

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1.14.3 The main deck cargo compartment in the B-747 combi is a Class B compartment as defined by FAR 25.857(b) (App I p 1). The compartment is equipped with a dual smoke detection system. The CVR recording confirmed that the detection system in both zones provided a warning to the flight crew. There is no evidence that the flight crew was aware of any indications of fire prior to the main deck cargo warning. None of the warning system was recovered from the ocean.

The Flight Manual approved for the aeroplane does not prescribe emergency procedures for a main deck cargo fire but these procedures are contained in the Operations Manual and are included in the operator's emergency checklist carried in the cockpit (App I p 2 -3). The checklist specifies that the flight crew should don their oxygen masks (and smoke goggles, if needed) and that a flight attendant must don an oxygen mask and portable oxygen cylinder and at the captain's direction enter the compartment. The flight attendant must then close the partition door, unclip the fire extinguisher from its stowage, unclip the cargo net gate, remove the 3m long applicator from its stowage and attach it to the extinguisher nozzle, find the source of the fire and apply the extinguishant. The aeroplane must then be landed at the nearest suitable aerodrome.

The flight crew is referred to the Upper and Main Deck Smoke Evacuation checklist from the main deck cargo smoke/fire procedure "if a smoke condition exists in the passenger area." This procedure instructs the non-flying pilot to determine the status of smoke in the cabin, and outlines a descent to 14,000 feet or the Minimum en-route Altitude (MEA) "if an immediate landing cannot be made and smoke condition is extremely severe". The procedure also calls for the crew to be on 100% oxygen, with smoke goggles on if necessary. The pilot not flying is to identify the cabin doors to

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be opened for the smoke evacuation. The aeroplane is depressurized, is slowed to below 200 knots, and the doors to be opened placed in manual at the captain's direction. The captain stated to Mauritius Approach control that the aeroplane was in a descent to FL 140 due to smoke in the aeroplane. Cockpit smoke evacuation procedures are not used unless the smoke source is inside the cockpit.

None of the cockpit oxygen masks or system were recovered for examination. Similarly, none of the fire fighting equipment for the main deck cargo compartment was found. It was noted that two of the cargo barrier net clips were unclipped at the release fittings. No other evidence was found to positively establish whether or not fire fighting procedures were performed.

1.14.4 There was a total of eight 2.5 lb Halon 1211 fire extinguishers installed in the passenger and flight deck areas of the aeroplane. Three 3.63 lb water extinguishers complete the portable fire extinguisher complement that was available in the passenger cabin and cockpit. Of these, one Halon extinguisher that was installed at door 2R was recovered with the floating debris. The bottle was full, but there was some melted nylon present on the outside surface. All these fire extinguishers were checked and recertified during 1987. (App I pp4 - 16).

1.14.5 Supplemental oxygen is provided by separate fixed systems for the flight crew and passengers, and portable oxygen bottles are positioned throughout the cabin and cockpit for use if needed. Individual oxygen masks are automatically released from the passenger service units when cabin altitude is at or above 14,000 feet. The B-747 Operations Manual warns that passenger oxygen use should be discontinued "below 14,000 feet when smoke or an abnormal heat source is pre-

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sent. The use of passenger oxygen will not prevent passengers from inhaling smoke at any altitude". (App I p17).

1.14.6 Numerous articles of cargo carried in the main deck cargo compartment and also compartment structure, fittings and components were damaged by fire. Many of the cargo articles and all the packing materials used were flammable. The cargo was largely comprised of electrical components and parts (mainly computers), hardware, paper articles, textiles and sports equipment (App I pp 18-20). Inquiries revealed that several computers and some computer circuit boards were fitted with either nickel cadmium or lithium batteries. Visits to the places of business of 66 consignors revealed that packing materials were mainly polystyrene, polyurethane, polyethelene sheeting and paper. Light articles such as computers and parts were packed in cartons while heavy units such as machines were either in wood crates or wood boxes. (App I pp 21-28). The crates, boxes and cartons were stacked approximately 2 m high, on 6 pallets designated PL, RL and SL from front to rear on the left side of the main deck cargo compartment and PR, RR and SR on the right hand side. The base dimensions of the pallets were 3,175m x 2,235 m for PL and SL and 3,175 m x 2,438 m for RL, PR, RR and SR. The longitudinal aisle width between two 2,235m wide pallets is 48,75 cm (19½ inches) and 9,062 cm (3 5/8 inches) between two 2,438 m wide ones. The left front (PL) and left rear (SL) stacks had been covered with polyethelene sheeting. The stacks had been secured to the pallet bases with nylon nets.

The pallets on which particular cargo consignments were placed, could only be determined from the master air waybills as only these waybills had been recorded when the pallets were made up, but many of the master waybills were consolidations of house waybills from consignors. This means that a consignment on one master waybill was spread out on two or more pallets, for example: Master air waybill No 4852 was a consolidation of 36 house waybills mentioning the articles despatched. The packages containing these articles were placed on pallets PR, SR and RL.

From the retrieved cargo items and from photographs taken of items on the sea bed it was determined that most of the cargo showing evidence of heat were on pallets PR (right front), RL (left centre) and SR (right rear). No heat exposed cargo items on pallets PL (left front), SL (left rear) and RR (right centre) were found (App.I pp 29-39).

1.14.7 The operator was not aware of any dangerous cargo in the aircraft and had assured that cargo handling would be in accordance with procedures laid down by the International Air Transport Association (IATA) (App I pp 40 - 42). The Operator's Manager in Taipei stated that he would have been informed of any dangerous cargo but he had not received such information. He further stated that security measures at Chiang Kai Shek Airport were above average (App I pp 43 - 45). Security of cargo at Chaing Kai Shek Airport was investigated and found satisfactory (App. I p46). Taiwan's Commissioner for Customs had conducted random sampling of the cargo consignments from Taiwan before they were loaded on the aeroplane. A computer selected 10 house waybills and one master waybill out of 111 bills. It was found that the items in the consignments agreed with the respective documents. (App I p46-49). The Chief of the South African Defence Force confirmed that no weapons or explosive devices were carried in the aeroplane for the SA Defence Force (App I p 50). The Executive General Manager of Armscor stated that there was no consignment of cargo to or from Armscor on the aeroplane. (App I p 51).

Lithium batteries and activated carbon are listed as dangerous goods in the Technical Instructions for Safe Transportation of Dangerous Goods by Air (Doc 9284 - AN/905) published by the International Civil Aviation Organisation (ICAO) (App I pp 52-53). Six consignments of electronic equipment contained small lithium battery cells fitted to circuit boards. These cells were considered non dangerous as Special Provisions A 45 of Doc 9284 - AN/905 had apparentely been met (App I pp 54-55 and K pp 1-18/5). A small quantity, 300 g, granulated activated carbon was carried in the lower cargo hold. According to Special Provision A51 of Doc 9284-AN/905 granular activated carbon is considered non-dangerous if cooled for more than 8 days since manufacture (App I p 55). The manufacturer stated that the activated carbon in the consignment had been cooled for longer than 180 days after production.

1.15 SURVIVAL ASPECTS

On 27 November 1987 at 23:50 the approach controller at Plaisance Airport declared an emergency and an ALERFA was issued, followed by a DETRESFA at 00:40 on the 28th. At about this time two search and rescue co-ordinators activated the Search and Rescue Centre (SARC) (App J p 1).

At 01:15 on 28 November 1987 an ALERFA - DETRESFA was sent to the civil aviation authorities and the Search and Rescue Centre (SARC) of the State of Registry. Plaisance ATC was asked if assistance was required and he was informed that a Lockheed 382 aeroplane would be ready to depart from Jan Smuts Airport at 08:00 on 28 November 1987. (App J p 4)

At 02:29 an Air Mauritius helicopter and a Mauritius Police helicopter departed for a search North of Mauritius. They were followed at 02:40 by a DHC-6 (Twin Otter) of Air Mauritius and a Transall of the French Air

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Force at 02:40. The search areas were extended to areas West, North East and South West of the island but nothing was found. At 12:47 the crew of a Beech 18 aeroplane, who took part in the search on their own initiative, saw wreckage pieces 136 nm north east of Plaisance (App J p 7). At 15:20 the SARC issued a situation report giving the following information : "Position of accident site at 1904S and 5936E. One empty dinghy and some debris located including one escape chute, something resembling a kerosene tank and some luggage. Two ships proceeding to the accident site, estimated time of arrival 21:00. A search craft has dropped an emergency locator beacon to mark the accident site. The search will continue at first light (01:12) on the 29th November. French C160, United States of America (USA) P3 Orion and Air Mauritius Aircraft will continue search for survivors as from dawn on 29th. Sea search is being carried out by a Mauritian navy vessel and other fishing vessels operating in the region". (App J p 4).

On 29 November at 02:56 the wreckage pieces were re-located by the crew of a Transall aeroplane and the ships started with retrieval of bodies and floating wreckage. This was a slow process as floating objects were spread over a large area.

On 30 November at 07:30 it was decided, after much deliberation, to terminate the search for survivors and concentrate on recovery of wreckage pieces. By this time mutilated human remains were retrieved but only 8 bodies were substantial enough for medico-legal post mortem examinations. The natures of the injuries indicated that the impact forces were far too high for survival.

The following organisations had immediately reacted positively to the search and rescue operations :

Mauritius Marine authority
National Coastguard of Mauritius
Helicopter Section of Mauritius Police
Air Mauritius

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French Air Force and Naval Base at Reunion
United States Navy at Diego Garcia
Perth Rescue Co-ordination Centre Australia
SARSAT Toulouse

1.16 TESTS AND RESEARCH

1.16.1 In an endeavour to determine a probable source of energy that could have ignited the cargo, special attention was paid to lithium battery cells installed in some computers and electronic equipment carried as cargo, as reports have been received that certain types of lithium batteries had exploded in emergency locator beacons e.g. those in which sulphur dioxide was used as electrolyte. Six small cells of the kind installed in the electronic equipment were examined by an expert (App K pp 1-18). He reported **inter alia** that two battery cells were lithium - thionyl chloride types, two of lithium-carbon monofluoride and the other two nickel-cadmium. He concluded with the following summary :

"Characteristics and safety aspects of nickel-cadmium, lithium-carbon monofluoride and lithium-thionyl chloride batteries that were on board the SA Helderberg have been reported. All batteries sent to the CSIR (Council for Scientific and Industrial Research) for investigation were of small size either coin or cylindrical design and low capacity (less than 1900 mA/hr). The nickel-cadmium batteries (some of which were believed to be in a discharged state) and Li/CFx coin cells are generally recognised as being very safe to transport. Low-rate lithium-thionyl chloride cells have been widely accepted for use in consumer applications and during storage are generally regarded to be safe. However, if these cells are abused, for example by sudden shortcircuiting or excessive heating, the possibility of these cells exploding cannot be entirely discounted." (App K p17)

1.16.2 The FAA appointed a special review team in January 1988 to evaluate the adequacy of existing criteria for the certification of main deck class B cargo compartments. (App K pp19-45) This team concluded the following (App K pp 19-20).

(1) The existing rules, policies and procedures being applied to the certification of class B cargo or baggage compartments in terms of smoke and fire protection are inadequate.

(2) The use of pallets to carry cargo in class B compartments is no longer acceptable

(3) While entry into the cargo compartment is available, not all cargo is accessible.

(4) It is unlikely that personnel would have the means available to extinguish a fire (particularly a deep-seated fire)

(5) The reliance on crew members to fight a cargo fire must be discontinued.

(6) The quantity of fire extinguishing agent and the number of portable extinguishers are inadequate.

(7) The level of visibility available in a smoke filled cargo compartment is not adequate for locating and fighting a fire with a portable fire extinguisher.

(8) Most existing transport aeroplane smoke or fire detection systems were certified prior to FAR 25

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Amendment 25 - 54 and are incapable of giving timely warning.

(9) There were differences in the smoke testing procedures and criteria used from manufacturer to manufacturer, prior to issuance of FAA Advisory Circular (AC) 25 - 9 (App L pp 159 - 171)

The team recommended that no new main deck class B compartment designs be approved to the existing class B criteria and that main deck cargo compartments provide a level of safety equal to class C compartments or that cargo be carried in fire resistant containers meeting class C requirements including smoke detection and fire suppression capability. Changes to the rules are being considered. (App L pp 172 - 178)

1.16.3 Many of the floating wreckage pieces that had been recovered shortly after the accident, were analysed for explosives by forensic scientists. No signs of explosives were found. (App K p 46).

1.16.4 The tape recording of the cockpit area microphone was examined in search of a fuselage vibration signature which could indicate an explosive cause of the cargo fire. No recognisable signature was found. (App K pp49-63).

* 1.16.5 Numerous specimens of aeroplane parts and articles from the passenger cabin and main deck cargo compartment were examined by an independant scientific institution in order to identify certain objects and materials, to determine temperature ranges at certain positions, to determine melting points of heat damaged components and to search for evidence which can be used to establish a probable cause

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of the fire which apparently started in the main deck cargo compartment. (App K pp 64-119/4). The most significant findings can be summarised as follows :

(1) The metal buckle of a carry-on bag had melted at one end. The melting point of the metal was found to be 327°C . (App K p 67). The assumed owner of the bag had been allocated seat no 42B in the rear-most row.

(2) The temperature in the main deck cargo compartment had ranged from 240°C at the rear end to 600°C at the partition between the cargo and passenger compartments. (App K p 69).

(3) A globule of molten nylon 6.6 found on the rearmost galley ceiling support structure contained a 3,1 mm diameter metal ball. Control cable pulleys in the area are made of nylon 6.6 and fitted with ball bearings having 3,1 mm diameter balls. (App K p 84).

(4) A pantihose in a foreign toilet bag was found melted to a heat damaged pallet load tie down net. Particles of copper, iron and melted plastic material were found inside the pantihose. Holes caused by hot particles were noticed in the hose and the toilet bag. Molten metal and molten plastic droplets were found on the netting. (App K pp 87 - 88).

* (5) Sections of the 9g cargo barrier net had been heated to its melting point and the molten polyester net material then smeared over contaminants during the impact. (App K p 89).

* (6) Small pieces of glass were found driven into fragments of crating wood. The glass was similar to that of computer monitors carried as main deck cargo. (App K p 90).

(7) Spherical iron particles were found in the insulation of an unindentified piece of electrical conductor. The particles showed air flow patterns which indicated that they were travelling at high velocities while in molten states. (App k P 90).

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(8) The solder points inside the CVR started to melt at 215°C but components such as transistors seemed intact. (App K p 90).

(9) Examination of two 1/8" diameter flight control cables installed in the crown of the main deck cargo compartment revealed that they had been heated to a temperature in the region of 700°C at their fracture points. From tensile tests it was apparent that a cable heated to 700° C will break if a tensile load of between 56 and 100 lbs is applied to it. The minimum breaking strength of a sound cable is 2000 lbs. (App K pp 91-92/1).

* (10) Microscopical examination of a black bag revealed the presence of tiny rust spots and a round black particle which was similar to those found in the electrical conductor mentioned above. (App K p 92/1

1.16.6 The aeroplane manufacturer advised that a slack elevator control cable would not allow overcontrol inputs. A completely slack cablé would result in a neutral elevator which would be mechanically driven to neutral by a spring loaded roller

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and cam arrangement. The cable tension regulator can take up 5,05 inches of cable slack. (App L p 66/1).

1.16.7 The manufacturer of the aeroplane analysed the structural capability of the cargo compartment crown section where the most heat damage was observed i.e. between body stations 1640 and 1960. The material allowables used are the properties at room temperature. (App K pp 120-132). The results can be summarised as follows :-

(1) During level flight (1g) and manoeuvres within the operational spectrum (1 g ± 0,3 g) the fuselage monocoque structure (skin and stringers) above the main deck floor is subjected to tensile loads.

(2) Damage to the crown structure is more critical than below stringer 4.

(3) The maximum operating manoeuvre loads are 1 g ± 0,3 g. This represents an operational flight spectrum between 1,3 g and 0,7 g.

(4) A 1,3 g manoeuvre is the maximum operating flight condition at cruise altitude combined with the normal cabin pressure of 8,9 pounds per square inch (psi).

(5) At the maximum operating manoeuvre load of 1,3 g without cabin pressurisation the structure will tolerate damage to the skin between stringers 13L and 13R even if the 26 uppermost stringers are all damaged. With the cabin pressurised to 8,9 psi the structure will tolerate skin damage between stringers 5L and 5R even if the 10 uppermost stringers have fractured.

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(6) The fuselage skin panels can sustain operating loads of 1,3 g plus 8,9 psi cabin pressure if the 38 uppermost stringers have fractured.

1.16.8 Tests with a Boeing 747 "Combi" simulator showed that the emergency descent time from FL350 to FL140 was 3 minutes 30 seconds. The pitch angles were 15° nose down at entry of the descent and 10° nose down when the aeroplane was stabilised in the descent (App K p133)

1.17 ADDITIONAL INFORMATION

1.17.1 The electrical wiring in the main deck cargo compartment was routed in the fuselage crown area on the left and right sides and identified as raceways G and H respectively. Each raceway comprised several channels and each channel in turn comprised several groups of wire bundles relating to the various systems (App L pp 1 to 4) Examples of these systems are the CVR, DFDR, automatic pilots, yaw damper, stabiliser electric trim, empennage control surface position indicators, lights and interphone system.

Circuit breakers installed at various locations, many of which are in the cockpit, provide protection for all wiring by opening in the event of short circuits, thereby isolating the affected system. In the event of an intense fire in the main deck cargo compartment it is possible that all or many of the wire bundles in raceways G and H would be damaged causing short circuits. This would result in the opening of related circuit breakers, a possible total of 80, of which 58 are located on various cockpit panels. (App L pp 11 - 12). Opening of the circuit breakers would be accompanied by cockpit warnings and indications such as illumination of amber lights, flashing red lights and gauge indications. (App L p 3 and 60).

The horizontal stabiliser trim is normally electrically controlled and hydraulically operated but can be controlled manually by means of levers and cables in the event of an electrical system failure. The elevators and rudders are cable controlled and hydraulically operated. All of these control cables are routed along the centre of the fuselage crown area and so are the pitot pressure and static tubes to the rudder ratio control modules, the pitot tubes to the elevator Q feel unit and stabiliser rate control sensing unit. If the control cables and/or the fuselage structure were not severely damaged by heat there should not have been a loss of pitch and yaw control.

As the electrical wiring, pitot pressure and pitot static pipe lines to the pitch and yaw control units had probably been damaged by the fire, the manufacturer of the aeroplane was requested to advise what the effects of such damage could have been on the flight characteristics of the aeroplane. The following answers were given: (App L pp71-74)

(1) Loss of pitot static pressure to the elevator feel system.

The elevator feel system is a purely passive system, which means that the elevator feel system cannot cause elevator movement by itself. Even in the event of complete loss of pitot static senses a positive stick force always remains, e.g. 9 lbs at 2½° of up elevator instead of 49 lbs under normal conditions.

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(2) Loss of associated electrical wiring to the elevator feel computer.
Loss of all wiring (shorted to ground) to the elevator feel computer would result in an elevator feel light on the master caution panel (assuming that panel still has 28 VDC power) and the autotrim threshold could go to minimum (if autopilot is still operative and engaged); there would be no effect on control. The feel force for this occurrence would be normal as no electric power is used in the feel computation function.

(3) Loss of all elevator autopilot channels, i.e. manual control.
Loss of pitch autopilot presents no hazard. The elevators remain centered by the feel unit springs.

(4) Loss of a combination of the above.
Reversion to light feel forces under manual elevator control is easily handled by the pilot. This was demonstrated as part of the certification process. It should be noted that since the amount of required column movement for most flight operations is small, the difference in stick force with and without the feel system is also small and the amount of column movement that a pilot would make, even before noticing the lower force, is likewise small.

(5) Loss of pitot static pressure to stabilizer trim system.
As with the feel computer the static source is at outside atmospheric pressure. At 19 000' and above the stabilizer trim rate is at minimum, it would then vary with altitude down to 16 000' where the trim rate would be maximum. Stabilizer trim rates range from 0.2 to 0.5 degrees/second in manual control and from 0.1 to 0.25 degrees/second under autopi-

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lot control. These changes in trim rate do not affect controllability.

(6) Loss of associated electrical wiring, i.e. main electrical control inputs and autopilot inputs.
Loss of electrical connections to the stabilizer trim would result in the loss of stabilizer trim from wheel trim switches and/or autotrim if autopilot were still engaged. The stabilizer trim brake release lights may illuminate if wiring to switch(s) are shorted and if 28 VDC is still available at the master caution panel. If the stabilizer starts trimming from other than the autopilot, the autopilot would disconnect.

(7) Loss of any combination of the above.
No combination of the above can create a control problem.

(8) Loss of the Yaw Damper System.
The yaw damper suppresses the basic aeroplane dutch roll mode and provides modal suppression to reduce fatigue loads on the structure in turbulence. At worst the aeroplane could sustain a low amplitude dutch roll after a gust and slowly damp out without pilot correction. Handling characteristics without yaw damper, light feel forces, and higher than normal trim rate are not seriously degraded as only the light feel forces would even be noticed.

(9) Loads on aeroplane structure due to the loss of any single or a combination of all of the above-mentioned systems.
The mentioned systems: Stabilizer rate, elevator control forces and yaw damper are tailored for best possible handling qualities and passenger comfort

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rather than structural protection by limiting pilot manoeuvre capability in manual flight.

1.17.2 The control relays for the pressurisation system outflow valves were mounted on the P85 panel beneath the flight recorders. The operating temperature range of these relays is from -65°C to +85°C.

The aeroplane manufacturer advised that failure times of the relays are dependant on test temperature and whether or not a relay is being repeatedly energised or de-energised (switched). Normal automatic operation would not result in the relay being switched. Testing of the relays indicates that at 300°C the switching capability may be lost in approximately 6 minutes when the relay is repeatedly switched during the test period but may be operable up to one hour without prior switching. At 500°C the times are approximately 3 minutes and 6 minutes respectively. The lost switching capability is due to softening and flowing of the arc barrier material around the contacts. (App L p 67).

Heat damage to the control relays could have caused the outflow valves to remain in the normal cruise position in which event the crew could have experienced difficulty to depressurise the aeroplane in order to evacuate smoke from the cabin. (App L pp 68-69)

1.17.3 If essential AC and DC powers were in fact lost when the pilot said, "Now we have lost a lot of electrics we have'nt got anything on the on the aircraft now", the VHF communications indicate that the standby 28V DC bus was still powered.

The No 1 VHF transceiver, the No 1 ILS and the marker beacon were all powered from the standby 28V DC bus which was in turn powered from the battery bus via the 28V

DC "hot bus". The static inverter that supplied the 115V AC power to the standby horizon unit was also powered from the battery bus. (App L pp 76-77).

1.17.4 The main deck cargo compartment of the Boeing 747 "Combi" aeroplane is classified as a class B cargo compartment. Fire protective measures for certification of the aeroplane were based on the following Federal Aviation Regulations (FAR's) which were current at the time.

FAR 25.857(b) (App L p 79) defines a class B cargo compartment as one in which :-

(1) There is sufficient access in flight to enable a crew member to effectively reach any part of the compartment with the contents of a hand fire extinguisher.

(2) When the access provisions are being used, no hazardous quantities of smoke, flames or extinguishing agents will enter any compartment occupied by the crew or passengers.

(3) There is a separate approved smoke or fire detector system to give warning at the pilot or flight engineer station.

(4) There is a fire resistant lining.

FAR 25.851(a)(4) (App L p78) prescribes that an approved fire extinguisher must be readily available for use in a class B cargo compartment. It must have a type and quantity of extinguishant appropriate to the kinds of fires likely to occur.

FAR 25.853 (b) (App L p 79) specifies fire protection criteria that materials used in cargo compartments must comply with. (App L p 86).

FAR 25.855 (App L p 79) requires cargo compartments to be free of wiring, equipment or accessories whose failure would affect safe operation unless such items cannot be damaged by cargo, or their failure will not create a fire hazard. Cargo must not interfere with the functioning of fire protective features and heat sources must not ignite cargo. In addition flight tests must be conducted to show compliance with 25.857 above concerning -

(1) Compartment accessibility;

(2) The entry of hazardous quantities of smoke or extinguishing agent into compartments occupied by the crew or passengers.

FAR 25.1301 (App L p 81) requires that installed equipment must be of a kind and design appropriate to its intended function and function properly.

FAR 25.1309 (App L p 82) requires systems to be designed and installed in such a manner as to ensure that they perform their intended functions under any foreseeable operating condition. Systems must also be designed to prevent hazards to the aeroplane if they were to malfunction or fail.

1.17.5 The fire protective certification requirements and the relevant design features of the aeroplane can be summarised as follows :

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(1) The 9600 cubic feet main deck cargo compartment is separated from the passenger compartment by a partition fitted just forward of the side cargo door at fuselage station 1723. (App L p 89). The 25 mm thick partition panels are constructed of Nomex honeycomb core and fibre glass face sheets. The partition is not an air tight seal between the two compartments. It is intended to provide a restriction that aids in air flow directional control within the aeroplane (App L p 105). Air is introduced into the compartments just below the ceiling levels, passes through the compartments and exits through side-wall grilles at floor level to move downward towards the rear to the two outflow valves located aft of the lower cargo hold. At the same time some air flows into the overhead space above the main deck passenger compartment and moves aft (App L p101). During normal conditions the recirculation fans pick up air from this area and return it to the distribution system. It is a requirement however, to shut down the recirculation fans if fire or smoke conditions are encountered. When the aeroplane is used in the Combi configuration a flow reducing valve in the cargo compartment distribution duct is set to reduce air flow into the compartment. Under normal conditions the air pressure in the cargo compartment should thus be slightly less than in the passenger compartment. This pressure differential has not been measured but during certification test flights it was observed that smoke did not penetrate into the passenger compartment even when the access door was ajar (App L p106). Thermal expansion caused by a fire has apparently not been considered. Tests to show non-ingress of flames into the passenger compartment have not been conducted. (App L pp 185-186). A computation by the FAA

showed that the effect of thermal expansion could have caused smoke and flames to enter the passenger compartment since a fire producing a constant 10 000 BTU's per minute would eliminate a differential pressure of 0,1 " of water within a few minutes under normal ventilation conditions (App K p 29). The smoke generation used in the certification tests produced a thermal release of about 6000 BTU's per minute. (App L p 186) Polystyrene and polyurethane produce 18 100 and 10 300 BTU/lb respectively. (App L p 188). The soot deposits in the passenger cabin and in the breathing air passages of accident victims and fire damage to the rear galley support structure seem to verify the FAA computation.

There are no ceiling panels in the cargo compartment. Insulation blankets are fitted to protect the fuselage structure. (App L p 102). These blankets had been retained in position by means of nylon fasteners. As many of the fasteners were found melted and as sooting of the exposed skin had occurred, it can be assumed that some of the blankets had become detached. The side panels are similar to those in the passenger cabin.

The empennage flight control cables run along the compartment roof.

The electrical wiring in the main deck cargo compartment does not include any main bus wiring

(2) Access to the cargo compartment from the passenger compartment is first through a door in the partition at the end of the left side passenger aisle and then through a "gate" in the cargo barrier net which

is spanned across the front end of the compartment (App L p 118). The "gate" is opened by unclipping the left hand lower portion of the net. The partition door is normally kept locked in flight but the key is stowed next to the door. A 16 lbs (7,25 kg) Halon 1211 fire extinguisher is stowed next to the access door inside the cargo compartment. A 2,5 m applicator or wand with a curved end is stowed on the cargo barrier net, adjacent to the entry gate (App L pp 148-149). This wand can be attached to the fire extinguisher hose nozzle to apply extinguishant high up and on top of the cargo stacks. The amount of fire extinguishant is considered sufficient for 1250 square feet of floor area where moderate size fires and ordinary hazards can be expected in a warehouse. The floor area of a 7 pallet combi is 880 square feet (App L p 100). The continuous discharge time of the fire extinguisher is 12 seconds.

(3) The main deck cargo compartment is equipped with a smoke detection system. When smoke is detected through any one or both of the sampling manifolds located in the cargo compartment crown area the flight crew is warned by a fire warning bell and warning lights (App L p 104). At the time of certification of the particular aeroplane the FAA prescribed that smoke detection must occur within 5 minutes of initiation of smoke generation (App L p 99).

(4) The lower cargo hold was fitted with photo-electric smoke detectors in each of the three compartments. Smoke in any of the compartments would have activated the annunciator lights on the pilot's overhead panel and the flight engineer's panel. The two freon gas fire extinguishers (105 lbs and 60 lbs) could be discharged electrically into any of the three com-

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partments by appropriate switch selection on the flight engineer's panel.

The auxilliary power unit (APU) compartment was fitted with continuous loop heat sensors in the upper and lower areas and would have warned the flight crew of dangerous temperatures by means of annunciator lights on the pilot's overhead panel and the flight engineer's panel. The 18 lbs freon gas fire extinguisher is electrically discharged into the APU compartment.

1.17.6 A NTSB expert on fires gave the following interesting view on the aeroplane's fire protection : (App L pp 179 - 184)

(1) In the case of pallet stacks covered with polyethelene sheets the smoke from a smouldering fire low down in the centre of a stack would be trapped under the cover and eventually escape at the bottom to flow out through the grilles at floor level. Only when the temperature of the air in the stack reaches about 250° C to melt the polyethelene, will the smoke rise to enter the sensing manifolds. When this happens the materials in the stack will be sufficiently preheated to provide a very rapid fire growth. By the time a crew member enters the compartment it will in all probability be too large a fire to extinguish with a portable fire extinguisher. Even if a fire were detected early and firefighting took place quickly it may be very difficult to suppress a fire which originated in the middle of a large pallet, with a hooked wand (applicator).

(2) Access to various pallets is made between the pallets and the fuselage which is very restrictive. Under the most ideal conditions fire fighting with the equip-

ment provided would be difficult. During the search for the fire the firefighter has both hands occupied, one hand carrying the 16 lb extinguisher and the other holding the 10 ft wand. It must be remembered that the whole philosophy of fire protection in the combi relies on early detection, rapid location of the fire and extinguishing with Halon. Furthermore, early detection and suppression are dependent on the fire being on the outside edge of a pallet, not towards the centre of a given pallet.