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Air Safety Investigation Branch

ACCIDENT INVESTIGATION REPORT

Department of Civil Aviation
Australia

Boeing 707-321B Aircraft N892PA at Sydney (Kingsford-Smith) Airport, on 1st December, 1969.

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PAN-AMERICAN WORLD AIRWAYS INC.
BOEING 707-321B AIRCRAFT N892PA
AT SYDNEY (KINGSFORD SMITH)
AIRPORT, AUSTRALIA
ON 1st DECEMBER, 1969

The investigation of this aircraft accident was authorised by the Director-General of Civil Aviation pursuant to the powers conferred by Air Navigation Regulation 278.

Prepared by:
Air Safety Investigation Branch Melbourne
August, 1970

ACCIDENT TO BOEING 707-321B AIRCRAFT N892PA

SYDNEY (KINGSFORD SMITH) AIRPORT, AUSTRALIA

1ST DECEMBER, 1969

1 - INVESTIGATION

1.1 HISTORY OF THE FLIGHT

On 1st December, 1969, a Boeing 707-321B aircraft, registered N892PA, and owned by Pan American World Airways Inc., was scheduled to operate Pan American Flight 812 which is a regular public transport flight direct from Sydney, Australia, to Honolulu, U.S.A. The flight is conducted by Pan American World Airways Inc. under the terms of a Certificate of Public Convenience and Necessity issued by the Civil Aeronautics Board, U.S.A., and an International Airline Licence, Number 207, issued by the Director-General of Civil Aviation, Australia. The aircraft was under the command of Captain Wayne E. POULSEN, and the crew consisted of First Officer Jan A. MENKE, Second Officer Jackson I. NEWBERRY, Third Officer Glen J. KASER Flight Engineer Harry B. HAISFIELD and Stewardesses Mary E. SKELTON, Linda L. McLENNAN, Ann K. HOFSTETTER, Veronica BIELAWSKI, Lillian T. YOSHIOKA and Isabella A. McCUDDEN. There were 125 passengers on board the aircraft.

The scheduled departure time for Flight 812 was 1745 hours Eastern Standard Time (EST).

A flight plan, which was submitted to the Sydney Air Traffic Control Centre at 1609 hours, indicated that the flight would occupy 8 hours and 57 minutes, and that the aircraft would cruise initially at flight level 330 and later at flight level 370. The plan also indicated that the aircraft had sufficient fuel on board for 10 hours and 29 minutes flight.

Having been provided with the calculated take-off gross weight, the flight crew completed the operational section of the take-off computation card which summarised the take-off conditions and, in addition, showed V speeds and the appropriate power settings for take-off, as follows :-

Take-off EPR	Static 1.83, Rolling 1.85
Take-off % N_1	108.8
Take-off flap setting	14^o
V_1 speed	138 knots IAS
V_R speed	145 knots IAS
V_2 speed	162 knots IAS
Rated EPR	1.60
Rated % N_1	100.1

While taxiing to the threshold of Runway 34, the crew completed the taxiing check-list and, in communication with Sydney Tower, received and acknowledged an airways clearance. The aircraft was initially instructed to line up on the runway and hold but, before it had entered the runway, this instruction was changed to a take-off clearance specifying that it would be a radar departure and that, after taking off, the aircraft was to turn right onto a heading of 050 degrees and to maintain 3,000 feet. This clearance was acknowledged and the pre-take off checks were conducted as the aircraft was turning onto the runway and lining up. These checks included a gyro compass comparison which was conducted as the aircraft heading passed through 010 degrees at which time the aircraft was 34 degrees from runway alignment. At 1757 hours Clipper 812 commenced its take-off from a rolling start.

The take-off was being carried out by the First Officer from the right hand seat and, after the First Officer had applied take-off thrust, the Captain took control of the throttles while the Flight Engineer made fine adjustments to the throttle settings to balance the power. As the aircraft accelerated at an apparently normal rate the Captain called progressively "80 knots your steering", "one hundred" and "vee one". Almost immediately after the "vee one" call the aircraft struck a flock of seagulls and there were two sharp reports from outside the aircraft. The Captain observed a decay in Number 2 engine EPR and aborted the take-off. The Captain's recollection of the sequence of events was that the power loss occurred shortly after the aircraft attained 100 knots and before V_1 speed and the recollection was shared by other crew members.

The Captain was scanning the engine instruments at the time the aircraft struck the birds and loss of power from Number 2 engine occurred. He saw the Number 2 EPR drop from its setting of 1.85 to about 1.55 and this initiated his decision to abandon the take-off. The Flight Engineer also saw the EPR drop to about 1.55 and called that there was a power loss. The Captain has stated that he applied considerable braking simultaneously with the selection of speed brake and reverse thrust and full braking almost immediately afterwards. During the early stages of the deceleration, the Flight Engineer saw several flickers of the anti-skid lights on the brake panel, he noted that the hydraulic pressure was normal and saw that the four reverse lights were illuminated and that the N_1 values on all engines was about 110% with EPR indications "well up". When the Captain took control of the aircraft the First Officer assisted by maintaining the nosewheel on the ground and keeping the wings level and, when reverse thrust was applied, he also placed his feet on the brakes and found that the pedals were fully depressed.

The aircraft over-ran the runway and struck sections of the approach lighting installation which caused the nose landing gear assembly and then the port main landing gear assembly to be removed. Finally, the nose of the aircraft came to rest partially embedded in soft ground 560 feet beyond the end of the runway and the crew and passengers then evacuated the aircraft.

1.2 INJURIES TO PERSONS

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Non-Fatal	-	-	-
None	11	125	

1.3 DAMAGE TO AIRCRAFT

The aircraft was substantially damaged.

1.4 OTHER DAMAGE

The runway approach lighting system sustained damage when the aircraft ran through the first bar of lights and then through the first two rows of barettes of the system.

1.5 CREW INFORMATION

Flight Crew

Captain Wayne Eddlemon POULSEN, aged 54 years, was the holder of Airline Transport Pilot Certificate No. 105289 with type ratings for airplane single and multi-engined land and sea, Douglas DC.3, DC.4, DC.6 - DC.7, Lockheed Constellation, Boeing 377 and 707/720 aircraft. He satisfactorily completed Boeing 707 captain qualification on the 19th November, 1965, and periodic proficiency checks at six monthly intervals since that time. His most recent proficiency check was satisfactorily accomplished on 21st November, 1969, and his most recent route check was on 20th September, 1969. Captain Poulsen held a first class medical certificate endorsed with the limitation that "the holder shall wear correcting glasses while exercising the privileges of his airman's certificate". His most recent medical examination was carried out on 19th November, 1969. His total flying experience amounted to 24,856 hours of which 7,656 hours had been gained on Boeing 707/720 type aircraft. Captain Poulsen had flown 66 hours in the last 30 days, 104 hours in the last 60 days and 173 hours in the last 90 days.

First Officer Jan Arthur MENKE, aged 33 years, was the holder of Airline Transport Pilot Certificate No. 1570315 with ratings for airplane multi-engined land and Boeing 707/720 aircraft. He also held commercial privileges in airplane single and multi-engine land. Mr. Menke was initially qualified as a Second Officer on Boeing 707 aircraft on 22nd March, 1966, and satisfactorily completed Boeing 707 First Officer type rating training on the 24th November, 1968. His most recent proficiency check was carried out on 28th October, 1969. He held a first class medical certificate with no limitations and his most recent medical examination was carried out on 28th August, 1969. His total flying experience amounted to 2,442 hours of which 2,082 hours were gained on Boeing 707/720 aircraft. Mr. Menke had flown 53 hours in the last 30 days, 108 hours in the last 60 days, and 164 hours in the last 90 days. During the last 90 days, he had carried out 20 take-offs and 17 landings.

Second Officer Jackson Irving NEWBERRY, aged 32 years, was the holder of Commercial Pilot Certificate No. 1714498 with airplane single and multi-engined land, and instrument ratings. His last proficiency check was carried out on 26th June, 1969. He also held Flight Navigator Certificate No. 1755552. Mr. Newberry held a first class medical certificate with no limitations. His most recent medical examination was carried out on 14th October, 1969. His total flying experience amounted to 3,085 hours of which 1,973 hours had been gained on Boeing 707/720 aircraft. During the last 30 days he had flown a total of 35 hours.

Third Officer Glen John KASER, aged 35 years, was the holder of Commercial Pilot Certificate No. 1406074 with airplane single and multi-engined land, and instrument ratings. His last proficiency check was carried out on 21st June, 1969. Mr. Kaser held a second class medical certificate with no limitations. His most recent medical examination was carried out on 11th April, 1969. His total flying experience amounted to 4,966 hours of which 4,678 hours had been gained on Boeing 707/720 aircraft. During the last 30 days, Mr. Kaser had flown a total of 53 hours.

Flight Engineer Harry Benjamin HAISFIELD, aged 28 years, was the holder of Flight Engineer Certificate No.1750566 with ratings for turbo-jet powered aircraft and Commercial Pilot Certificate No. 1626483 with airplane multi-engined land, Lockheed 382 and instrument ratings. His last proficiency check was carried out on 17th March, 1969. He held a first class medical certificate with no limitations. His most recent medical examination was carried out on 4th August, 1969. His total flying experience amounted to 3,494 hours of which 1,782 hours had been gained on Boeing 707/720 type aircraft. During the last 30 days he had flown a total of 55 hours.

Prior to reporting for duty on the flight on which the accident occurred, the flight crew were off duty for the preceding 29 hours 26 minutes.

Cabin Crew

Mary Elizabeth SKELTON, aged 30 years, commenced employment with Pan American Airways on 28th March, 1961 and was promoted to purser on 9th September, 1966. Her initial emergency equipment training was carried out during April, 1961 and her most recent emergency equipment training was completed on 26th June, 1969.

Linda Lee McLENNAN, aged 26 years, commenced employment with Pan American Airways on the 1st April, 1968 and was promoted to purser on 1st December, 1968. Her initial emergency equipment training was carried out during April, 1968 and her most recent emergency equipment training was completed on 22nd October, 1969.

Ann Kresin HOFSTETTER, aged 24 years, commenced employment with Pan American Airways on 12th August, 1966 and carried out her initial emergency equipment training in August, 1966. Her most recent emergency equipment training was completed on 21st July, 1969.

Veronica BIELAWSKI, aged 25 years, commenced employment with Pan American Airways on 7th August, 1967 and carried out initial emergency equipment training in August, 1967. Her most recent emergency equipment training was completed on 15th September, 1969.

Lillian Toshiko YOSHIOKA, aged 25 years, commenced employment with Pan American Airways on 7th October, 1968 and carried out her initial emergency equipment training in October, 1968. Her most recent emergency equipment training was completed on the 24th October, 1969.

Isabella Alexander McCUDDEN, aged 25 years, commenced employment with Pan American Airways on 20th May, 1968 and carried out her initial emergency equipment training during May, 1968. Her most recent emergency equipment training was completed on 21st October, 1969.

Prior to reporting for duty on the flight on which the accident occurred the cabin crew were off duty for the preceding 56 hours and 16 minutes.

1.6 AIRCRAFT INFORMATION

History

The aircraft was a Boeing 707-321B, Serial Number 20029, and had been owned and operated by Pan American Airways since manufacture. It was received from the manufacturer on 4th March, 1969 and the Certificate of Aircraft Registration was issued on 27th.March, 1969.

The aircraft had flown a total of 3,044 hours since new and had flown 930 hours since the last Equalised Service and 79 hours since the last Terminal Service. There was no evidence in the aircraft records of any engineering deficiencies which could have been relevant to the accident and all reported deficiencies had been corrected.

Loading

The maximum permissible take-off gross weight of the aircraft from structural considerations is 333,100 lb but the length of runways at Sydney imposes a weight restriction. The flight was planned with the selection of Runway 34 for take-off and in the forecast conditions of a surface wind from 010 degrees true at 15 knots, a temperature of plus 27 degrees Centigrade and a barometric pressure of 999 millibars and with the take-off to be conducted with the cabin pressurisation turbo-compressors turned off, the maximum permissible take-off gross weight was computed to be 303,100 lb. The load summary and weight and balance sheet prepared for the flight indicates that the take-off gross weight was to be 302,748 lb with the centre of gravity position at 24.2% mean aerodynamic chord.

When the loading of the aircraft was being planned, the required fuel for the flight was calculated to be 131,000 lb including an allowance of

1,000 lb for fuel which would be burnt off during taxiing before take-off. Prior to refuelling, the density of a sample of the fuel in the refuelling tanker was measured by Pan American Airways maintenance personnel and found to be 6.28 lb per U.S. gallon. It was then calculated that a quantity of 15,840 U.S. gallons was required to be added to the fuel already in the aircraft to produce the planned fuel load of 131,000 lb at blocks. The aircraft was refuelled according to these calculations.

During the investigation of the accident it was established that the metal hydrometer used to measure the fuel density was defective. The upper end of the graduated stem was split circumferentially at its junction with the end plate and this had permitted fuel to enter the instrument, causing it to float lower in the fuel sample and consequently indicate a lower than actual fuel density.

Subsequent to the accident, the density of the fuel in each of the aircraft's tanks was measured and the figure obtained was adjusted for the variation in temperature from that calculated to exist at the time of refuelling. The fuel density was found to vary between 6.58 lb per U.S. gallon and 6.59 lb per U.S. gallon, and the weight of usable fuel in the aircraft's tanks, at blocks, has been calculated to be 137,271 lb.

The contents of the aircraft's four holds were removed and weighed and cabin luggage left by passengers after the evacuation was also weighed. On the basis of these weighings and the recalculation of the fuel load, the gross weight of the aircraft at the time of commencement of take-off has been assessed as 309,560 lb.

1.7 METEOROLOGICAL INFORMATION

A route forecast covering the proposed flight was prepared by the Sydney Airport Meteorological Office at 1500 hours EST on 1st December, 1969 and this included a Sydney Aerodrome Forecast covering the period from 1745 to 2200 hours on 1st December, 1969. This forecast indicated that the weather at Sydney Airport at the time of the take-off would be fine, with no significant cloud and visibility of 15 miles, that the wind would be from a direction of 010 degrees true at 15 knots, that the temperature would be 27 degrees Centigrade and the QNH altimeter setting would be 999 millibars.

Prior to commencing to taxi for take-off the aircraft received, by radio, the current Automatic Terminal Information Service (ATIS) "Sierra", which advised that the wind was from the direction of 030 degrees magnetic at 15 to 20 knots with gusts to 25 knots, the temperature was 26 degrees Centigrade and the QNH setting was 999 millibars.

At 1800 hours, about one minute after the accident, a routine Aerodrome Weather Report produced by the Meteorological Office indicated that the wind was from the direction of 050 degrees true at a speed of 15 knots and that the temperature and QNH setting were unchanged.

The anemometer head from which the meteorological wind information is obtained is located some 30 feet above the ground at a position about midway along Runway 34 and 1,800 feet to the east of the runway. At 1759 hours the wind was fluctuating in direction from 040 degrees true to 060 degrees true and the speed was varying between 6 knots and 13 knots. Although the mean wind velocity at the time of the accident was 050 degrees true $9\frac{1}{2}$ knots and the corresponding mean headwind component was 5 knots, the headwind component could have varied between 2 knots and 9 knots within the limits of the fluctuations in the wind direction and speed as recorded on the anemometer trace.

1.8 AIDS TO NAVIGATION

Navigation aids were not a factor in this accident.

1.9 COMMUNICATIONS

Communications with the aircraft were normal.

1.10 AERODROME AND GROUND FACILITIES

Runway 34 is 8,900 feet in length and 150 feet wide and the runway alignment is 336 degrees magnetic (348 degrees true). The surface is composed of bituminous concrete material with the exception of 500 feet at the northern extremity which is of cement concrete. The elevation of the southern threshold of the runway is 16 feet and that of the northern threshold 7 feet. The high point of the runway is located 2,600 feet from the southern end and from this point there is a 0.22 per cent downslope to the north and a 0.18 per cent downslope to the south. There is a parallel taxiway on the western side of Runway 34 from which departing aircraft enter the runway at its southern extremity by a short taxiway at right angles to the runway centre line. Beyond the concrete section at the northern end of the runway is an area of sealed low strength pavement 300 feet in length and 200 feet in width. The first bar of the precision approach lighting system (Category 1) for Runway 16 consists of 22 lights mounted on fittings up to ten inches high and is located across this sealed section 218 feet from the end of the runway. Between the first and second bars of the system there are, at longitudinal intervals of 100 feet, four rows of three barette units. Each unit is comprised of a steel mounting frame fitted to carry five lights and set in a concrete base which in some cases stands above the level of the adjacent surface by up to seven inches.

The bituminous concrete was laid some 15 months prior to the accident and is a mixture of gravel and coarse and fine sand containing all sizes from $\frac{1}{2}$ inch downwards, held together with bitumen. At the time of the accident the surface was in excellent condition; dry, moderately textured, clean and free from oil and with the sand sizes showing through the bitumen film which is present when newly laid. For a length of about 700 feet in the vicinity of the 1,000 feet and 1,500 feet threshold markers there was some evidence on the surface of rubber deposits from the tyres of landing aircraft, but this had not reached the stage where removal was warranted. The 500 feet section of cement concrete at the northern extremity of the runway was a new textured surface in good condition.

1.11 FLIGHT RECORDERS

Flight Data Recorder

The aircraft was equipped with a Lockheed Aircraft Service Type 109C recorder. This flight recorder records vertical acceleration, heading, indicated airspeed and altitude against a time base by inscribing an aluminium foil medium with separate styli which are continually in contact with the foil and which move across its surface in response to variations of input data to the recorder.

The recorder was located in the tail cone of the aircraft and was not damaged in the accident. A post accident calibration check was conducted and confirmed the previous calibration for all parameters except that, in the recording of airspeed, there were inconsistencies at speeds below 100 knots. Specifications for the recorder, however, do not prescribe any standards of accuracy below 100 knots.

At Appendix C there is a graphical presentation of the flight data record for the period commencing with the turn toward the runway from the heading of 156 degrees maintained on the parallel taxiway and terminating just after the aircraft came to rest.

The heading trace indicates that the aircraft achieved the runway alignment of 336 degrees, 28 seconds after commencing the final turn onto the runway. The heading of 336 degrees was then maintained for 40 seconds after which there was a progressive 4 degree deviation to starboard, a 3 degree correction to port and then a further 5 degree deviation to starboard. The recording indicates that a heading change comprising an almost instantaneous port turn of 7 degrees, to a heading of 333 degrees, occurred as the aircraft came to rest. This turn was confirmed by ground marks and the indicated final heading corresponded with the measured heading of the aircraft at rest.

The vertical acceleration trace showed characteristics of a fairly slow taxi speed during the turn until the aircraft heading reached approximately 30 degrees from runway heading. Over the next 48 seconds, the acceleration trace showed excursions to a maximum of 0.3g which are typical of those inscribed during a take-off. The subsequent recording of a positive "g" of 1.48 and a reversal to 0.66g is consistent with observed recordings of previous landings during periods when reverse thrust was being applied. The largest excursions occurred over the last six seconds of the record of active vertical accelerations. During this period there were peaks of 1.64g, 1.82g, 0.49g and 0.32g which were obviously associated with the aircraft's passage through the area of the approach light installation.

In plotting the altitude trace, correction was made for the altimeter setting of QNH 999 millibars which existed at Sydney at the time of the accident. When this correction was applied, the recorded altitude of the aircraft, just prior to being lined up on the runway for take-off, was 17 feet which closely corresponds with the actual elevation of 16 feet at the southern end of Runway 16/34. There were characteristic aberrations recorded during the abandoned take-off and the final reading of the altitude trace was 17 feet.

The airspeed trace indicates that the aircraft was taxiing before take-off at 20 knots and, during the take-off roll, the recorded airspeed increased to a maximum of 139.7 knots in 47.6 seconds. From this time the airspeed decreased to 80 knots in 10.3 seconds, 60 knots in a further 3.2 seconds, 20 knots in another 12.3 seconds and zero in a further 4.5 seconds.

The recorded speed while taxiing before take-off is known to be inaccurate as calculations of the time and distance covered in the turn from the parallel taxiway to the runway indicate that the taxiing speed in this area was approximately 12 knots diminishing to about 8 knots in the latter part of the turn. In considering the recorded speeds during the deceleration phase, correlation of the graphs of airspeed and heading shows that the flight data recorder was recording airspeeds of 32 knots when other evidence clearly shows that the aircraft was stationary at the time. The airspeeds below 100 knots in the acceleration and deceleration phases have been plotted on the graph at Appendix C but they are considered to be inaccurate.

Although the peak speed achieved was recorded as 139.7 knots, bench tests conducted on flight data recorder equipment of this type indicates that, during an accelerate/stop type manoeuvre, significant under-reading of the peak speeds will occur. It was not practicable to quantify the extent of under-reading as related to the particular recorder in the circumstances of an actual accelerate/stop manoeuvre.

Cockpit Voice Recorder

A Fairchild Industrial Products Cockpit Voice Recorder Model A100 was installed in the aircraft and this recorder provides, on a continuous loop of magnetic tape, a record of cockpit conversations and ambient noises, radio communications and public address announcements. The recorder was undamaged in the accident and, at Appendix B, there is a transcript of the record of the last two minutes of cockpit voice recorder operation, covering the period from the beginning of the take-off roll until the aircraft came to rest.

There was good correlation between some events recorded mutually on the cockpit voice recorder and on the flight data recorder and the tape speed of the cockpit voice recorder was confirmed by correlation between mutually recorded items on the cockpit voice recorder and the Tower communications recorder, the latter having a time injection facility.

By relating the time interval between two events recorded on the voice recorder to the amount of travel of the flight data recorder tape between the same events, an average flight recorder tape speed of 0.142 inches per minute was obtained and this has been adopted as a time basis for the graph of flight recorder traces.

Correlation of events recorded on the cockpit voice recorder with those recorded on the flight data recorder was predicated on the simultaneous occurrence of aircraft passage through the heading of 010 degrees as evidenced by the flight data recorder and the gyro compass check heading call of "010 - now" as recorded on the cockpit voice recorder. This event is shown below the graph of flight recorder traces at Appendix C and has been given a time reference of "0". Other significant events recorded on the voice recorder and which are removed in time from this event have also been shown on the graph in a relative position to the flight data recorder traces.

Data in respect of the operation of the engines during the rejected take-off roll was derived from the voice recorder tape by sound spectrum analysis and this work was conducted by the National Transportation Safety Board. Details are given at Section 1.15 of this report.

1.12 WRECKAGE

The aircraft came to rest with its nose in soft mud 560 feet beyond the end of the runway (260 feet beyond the end of the low strength pavement) and 49 feet to the right of the extended centre line of the runway. At Appendix A - Fig. 1 is a diagram showing the position of the aircraft in relation to the runway, the path taken by the aircraft commencing with the first discernible wheel marks on the runway and the location of seagull carcasses found on and adjacent to the runway. Carcasses and pieces of carcass of approximately 17 seagulls were found on and adjacent to the runway between two points 5,760 feet and 6,900 feet from the southern threshold. The wheel marks of the aircraft could be discerned commencing at a point 6,570 feet from the threshold and until the aircraft came to rest.

The marks made by the aircraft and damage sustained by the approach lighting system provided evidence of the following sequence of failures. As the aircraft passed across the low strength pavement area it ran through the first bar of frangible approach lights, which are mounted on tubular fittings up to 10 inches high. The right hand nose wheel and Numbers 1, 3 and 4 pairs of main wheels, each contacted and broke off an approach light. The two main wheel tyres at Number 2 position passed over a steel mounting tube which had no light attached, and the tyre tracks and tread damage indicate that the tyres were punctured and burst at this point.

As the nose landing gear left the low strength pavement area it was detached from the aircraft when it struck the concrete base and steel mounting frame of an approach lighting barette. The lower part of the Number 2 engine cowling also struck one of the mounting frames in this row of barettes. The failed nose gear remained beneath the fuselage and was carried along with it, passing progressively rearwards along the fuselage and thereby causing substantial damage to the lower fuselage structure.

The left main landing gear struck the concrete base of a barette in the next row and was partially detached from the structure. The lower section of Number 1 engine lightly struck a steel mounting frame in the same row of barettes.

Shortly after failure of the main gear and about 45 feet before the aircraft came to rest, Number 2 engine contacted the ground resulting in partial upward failure of the nacelle strut and failure of the diagonal brace rear attachment. As the aircraft came to rest, it swung to the left and Number 1 engine also contacted the ground.

The damage sustained by the structure and the sequence of failures were, with one exception, consistent with the successive impacts with components of the approach lighting system and with the ground. The exception was that the Number 3 leading edge flap inboard carriage assembly was found to be cracked. There was no evidence of any resultant malfunctioning of the leading edge flap and the cracking is considered to have occurred prior to the accident and not to have contributed to it in any way.

A number of bird strikes had been sustained on the wing leading edges and the engine intake cowls of Numbers 1, 2 and 3 engines. The strikes were more numerous on the left wing and had been sustained with the leading edge flaps in the extended position. Although it was not possible to positively determine the number of birds struck, there was evidence of at least 11 separate bird strikes.

The investigation established that all flight control systems were capable of normal operation prior to the damage sustained in the accident. The trailing edge flaps were found in the normal take-off position of 14 degrees and the leading edge flaps were in the extended position. As selection of reverse thrust also retracts the leading edge flaps and as reverse thrust had been selected, functional testing of the system was conducted to resolve this apparent inconsistency. This established that the opening of the left main gear oleo safety switch, with the system in the reverse thrust configuration, would result in extension of the leading edge devices. In addition, marks on the Number 2 engine strut indicated that the leading edge flaps had moved towards the extended position after that engine had contacted the ground. It was concluded that the leading edge flaps extended after the failure of the left main landing gear and the resultant opening of the safety switch circuit.

The spoilers were found in the retracted position although the speed brake selector was in the extended position. This apparent inconsistency was resolved when testing established that the spoilers would have retracted within 25 seconds after the loss of hydraulic system pressure which occurred on failure of the landing gear.

The only pre-existing abnormality found in the examination of the hydraulic system was the presence of a small quantity of metal particles in the case drain filter of Number 3 engine-driven pump. Detailed examination disclosed no deficiencies in the pump and it is considered that it was operating normally at the time of the accident.

The damage exhibited by the landing gear wheels and tyres was consistent with the known impacts sustained by them. The tread of the tyres had adequate depth and the inflation pressures of those tyres which retained pressure were satisfactory. The landing gear wheels and the wheel brakes are considered to have been in a serviceable condition prior to the accident and all brake assemblies showed evidence of hard usage. The mainwheel fusible plugs were intact and this is considered to be due to comparatively rapid quenching of the wheel and brake assemblies from immersion in mud and the use of water spray by the Airport Fire Unit shortly after the aircraft came to rest.

There was good evidence from the tyre marks on the runway, and from the general condition of the brake assemblies themselves, that continual substantial braking action was achieved until the aircraft left the low strength pavement beyond the end of the runway. There was no evidence, from either the runway marks or the tyre treads, of any skidding. All relevant anti-skid system components were tested and examined and, although some minor deficiencies were found in three of the dual control valves, it is considered that they would have had no significant effect on the anti-skid functioning in the good runway conditions which prevailed. This belief is confirmed by the lack of skid indications on the tyre treads of the wheels involved and the consistent runway marking indicative of heavy and controlled braking.

All four engines were operating in the reverse thrust configuration when the aircraft came to rest and the testing of Numbers 1, 3 and 4 engines, and the examination and component testing of Number 2 engine, indicated that all four engines were capable of normal operation. The fuel tank selection was normal and no defects were found in the fuel system. It is concluded that the engines were fully serviceable at the time of the take-off.

There was foreign object damage in the compressor stages of all engines although, in respect of Numbers 3 and 4 engines, it was only to a minor extent. This damage is considered to have been caused by the ingestion of stones and dirt after the aircraft left the sealed surface. Although there was evidence from staining and bird remains that birds and pieces of birds had been ingested by Numbers 1, 2 and 3 engines, there was no evidence that the bird ingestion had resulted in any damage to Numbers 1 and 3 engines. In the case of Number 2 engine, Blade 14 in the first stage sustained a large deformation and the marking on its rear face, and the lack of notching and abrasion on the leading edge of Blade 15, indicate that Blade 14 suffered its major deformation prior to the general ingestion of foreign matter. Staining and bird remains on the inside of the intake cowl, the fan dome, and the inlet guide vanes indicate that at least one bird entered Number 2 engine intake. These facts, combined with the general resemblance of the Blade 14 damage to other known cases of bird ingestion, suggest that this damage was caused by one of the birds struck prior to the decision to discontinue the take-off. The ingestion of one or more birds and the observed damage to Blade 14 is considered to have been sufficient to cause engine surge and a power loss indication but it is not possible to state whether there would have been a permanent power degradation as a result of this bird strike. It is known, however, that all four engines achieved 110% N_1 during the deceleration and all EPR readings were noted by the flight engineer to be "well up". Thus it appears that Number 2 engine would have been capable of delivering substantial and possibly full power subsequent to the bird strike.

1.13 FIRE

There was no fire.

1.14 SURVIVAL ASPECTS

Immediately the aircraft came to rest the Captain ordered the flight crew to evacuate the aircraft but no announcement was made on the aircraft's public address system to ensure that the cabin crew and passengers carried out an immediate evacuation. The purser, seated at the rear of the aircraft, initially used the public address system to order the passengers to remain in their seats but an order to evacuate was shouted from the front of the aircraft and the stewardesses immediately opened the four main exit doors and rigged the escape slides. Due to the collapse of the nose wheel assembly, the door-sill of the front entrance door was only about two feet above the ground and an escape slide was not necessary. Similarly, the sill of the front galley service door, opposite the port main door, was close to the ground but the escape slide was deployed and, although it lay virtually flat on the ground, it was of some value in assisting the vacating passengers to negotiate an area of soft boggy ground in which the nose of the aircraft was embedded.

The Captain vacated the aircraft through the left flight deck window, the First Officer and the Third Officer through the right flight deck window, and the Second Officer, after assisting a stewardess to open the front main entrance door, left by that exit followed by the Flight Engineer. The flight crew then positioned themselves at the various exit points and adjacent to the wings and assisted the passengers to leave the vicinity of the aircraft. In the latter stages of the evacuation when no more passengers were vacating from the forward exits, the Captain and First Officer re-entered the aircraft and assisted the stewardesses in directing passengers towards exits which were not being used. They then made a final check through the length of the aircraft to ensure that the evacuation was complete and left by the rear main door escape slide.

During the take-off the stewardesses were seated adjacent to the four main exit doors and when the evacuation order was given they opened these doors promptly and assisted the passengers to evacuate the aircraft. The two starboard and the rear port over-wing exit windows were opened by passengers and two stewardesses came from the forward cabin area to assist passengers vacating the aircraft through these exits. At the completion of the passenger evacuation the stewardesses vacated the aircraft and assembled the passengers for return to the passenger terminal.

The left front over-wing exit was not opened and the rear galley exit was effectively blocked by a 96 year old blind and invalid woman and her 75 year old son, neither of whom spoke English. The woman was most reluctant to use the escape slide but a stewardess, assisted by the son, eventually forced her down the slide. They were the only two passengers who used this exit.

Approximately the following numbers of passengers used each of the remaining exits :-

Front main door	-	25
Front galley door	-	15
Rear Main door	-	25
Overwing exits	-	55 **

** Despite the fact that there were two exits available on the right side of the aircraft and only one on the left side, approximately the same number of passengers vacated from each side of the aircraft.

One obstruction to the evacuation was an oven which was dislodged from the forward galley and fell into the aisle. It was quickly removed and placed in the lounge area by a Company Flight Engineer who was travelling as a passenger in the front cabin area. Many passengers carried their hand luggage from the aircraft despite instructions and physical efforts by the crew to prevent this.

Evacuation of the aircraft was completed in less than two minutes.

The abandoned take-off was observed from the Control Tower and, when it became obvious that the aircraft would not stop within the confines of the runway, the Senior Tower Controller activated the crash alarm at 1759 hours. The Airport Fire Service responded promptly and five fire fighting appliances were at the accident scene within about 2½ minutes with at least one appliance being in position before passenger evacuation was completed. There was no fire and their activities were confined to cooling, with diffused water spray, the smoking main wheel brake assemblies.

As the aircraft came to rest the Senior Tower Controller alerted emergency services by the common call crash line to the Metropolitan Fire Brigade, Ambulance Service, Police and Hospitals. The first ambulance arrived at 1807 hours and by 1813 hours there were 20 ambulances and a medical team with three doctors at the scene of the accident. Their services were not required. Metropolitan Fire Brigade units arrived at the scene at 1812 hours and the first of some 17 police vehicles was in position at 1813 hours.

1.15 TESTS AND RESEARCH

Cockpit Voice Recorder

In order to derive data from the cockpit voice recorder in respect of the operation of the engines during the rejected take-off roll, it was arranged that a sound spectrum analysis be conducted by the National Transportation Safety Board in Washington D.C., U.S.A. An engine performance calibration tape was prepared with the co-operation of Pan American World Airways, who provided Boeing 707 aircraft N892PA for the tests and this was, in fact, the aircraft which had been involved in this accident. The analysis provided the following information pertinent to the circumstances of the accident and related in time to events featured on the cockpit voice recording. A datum was selected using the time at which the First Officer called "now" while conducting the gyro compasses check when the aircraft was turning to take up the runway heading before commencement of the take-off roll.

SECONDS	EVENT	SOUND SPECTRUM ANALYSIS DATA
00	Gyro compass check "Zero One Zero Now"	At this time two engines were at idle and two engines were at 82.5% N_1
01.7		Two engines commenced to advance towards take-off thrust.
05.0		The other two engines commenced to advance towards take-off thrust.
13.7		Take-off thrust was achieved by all four engines.
		110% N_1 was developed by all engines during the take-off run.
50.3	Sound of "Bang"	Sound identified as compressor stall.
51.2	"Got - loss of power"	
51.9	Sound of power levers hitting stops	There was a variation of power down to 93.9% N_1 during this period.
54.9		The lowest N_1 value occurred and then the N_1 value was increased in reverse thrust.
58.55		The maximum N_1 value was achieved by the last engine.
		Thrust was then stabilised at 110% N_1 and there were no variations of power during the deceleration phase nor was there any evidence of the sound of additional compressor stalling.

Accelerate/Stop Performance

An analysis of the aircraft performance was conducted using data derived from performance information provided by the Boeing Company, and from data obtained from the cockpit voice recording data and the flight data recorder read-out. The Boeing data provided speed/time/distance relationship in the acceleration and deceleration phases and included a transition delay time comprising the type certification transition delay times and a further delay for development of reverse thrust. Information was also provided in respect of deceleration, both with and without the use of reverse thrust.

The accelerate/stop performance information provided by the Boeing Company was based on the following circumstances and conditions :-

(a) aircraft gross weight of 309,400 lb;

(b) aerodrome pressure altitude of 390 feet;

(c) aerodrome air temperature 26 degrees centigrade;

(d) all engines operating throughout the take-off at take-off thrust and with the turbo compressors not operating;

(e) a head wind component of 10 knots;

(f) a level runway;

(g) take-off acceleration commenced from a standing start with full thrust achieved at brake release.

In providing the data, the Boeing Company factored the specified wind to compensate for the fact that surface wind velocities are measured at the elevated head of an anemometer. The head wind component used in these calculations was therefore 7.5 knots.

The information derived from the sound spectrum analysis of the cockpit voice recording provided data necessary to establish the thrust levels achieved during the development of full power for take-off. It also confirmed that, once full power was established during the take-off roll, power did not vary until the compressor stall associated with the bird strike occurred, and further, it established that an engine speed of 110% N_1 was achieved and maintained on all four engines during the deceleration phase.

The first step in the study was to determine how the aircraft, with an assessed gross weight of 309,560 lb, would have performed assuming that acceleration was commenced from a standing start with full thrust at brake release and continued to the V_1 speed of 138 knots; that there was recognition of engine failure at V_1, and that there were certification transit delay times in achieving the deceleration configuration using brakes and speed brakes but not reverse thrust. It was determined from the Boeing data that, in such circumstances on a level runway, the distance covered during the acceleration to V_1

would be 4,730 feet and the distance travelled from V_1 to come to rest without use of reverse thrust would be 3,100 feet giving a total distance of 7,830 feet. This distance was used as a basic distance for comparison purposes when determining the effect of actual runway slope, the overshoot in speed beyond that of V_1 before engine failure, the effect of a gross weight in excess of that flight planned and the effect of a lower than forecast head wind component. The effect of reverse thrust in reducing accelerate/stop distance was also considered as reverse thrust is not taken into account in the type certification accelerate/stop performance demonstrations.

To permit development of performance comparisons, a technique was devised to modify the Boeing speed/time/distance curves to account for runway slope, aircraft weight differences and for a zero headwind component.

Consideration was then given to the effect that the known circumstances, procedures and techniques affecting the performance of the aircraft in this occurrence would have on the distance travelled during the three phases of acceleration, transition and deceleration. As the wind speed and possible variations of wind speed could not be determined precisely, consideration was given to two assumed wind cases, one with a 10 knot head wind component and the other with a zero head wind component.

The elevation of the southern threshold of the runway is 16 feet and there is an upslope to the north of 0.18 per cent for 2,600 feet to an elevation of 21 feet followed by a downslope of 0.36 per cent for 4,000 feet and then an almost level runway to the northern threshold which has an elevation of 7 feet. Consideration was given to the effect that the runway slope might have had on the performance of the aircraft and it was found that it resulted in a reduction of the total distance by 25 feet.

The gross weight of the aircraft at the time of the take-off was assessed as being 6,800 lb in excess of that planned and from the performance data it was calculated that this excess weight increased the total distance in the accelerate/stop manoeuvre by some 200 feet.

Acceleration Phase

The take-off by the aircraft in this accident was a rolling start which was a continuation of a rolling entry onto the runway. In order to establish the entry speed of the aircraft, an incremental analysis was conducted of the heading changes against time as derived from the record of the flight data recorder. There is no unique solution to this problem, as different combinations of radius and speed can give the same rate of turn but, if it is assumed the nose wheel followed the taxiway guide lines during the period of constant turn rate just preceding the 010 heading call, the aircraft's speed at the time of the gyro compass check was 8 knots. The analysis also showed that the nose wheel of the aircraft would have been 160 feet from the runway threshold at the time of the 010 heading call.

Because the aircraft's position on the runway and its rolling speed at the point of gyro compass check were known, this point became a convenient reference to use in determining the distance travelled and the speed achieved while the engines were accelerating towards full power.

As the Boeing acceleration data is based upon full engine thrust at brake release from a standing start, it was necessary to consider the effect upon distance of the employment of a rolling start. The sound spectrum analysis established the engine speeds and power application times near the time of the gyro compass check and all engines achieved full thrust 13.7 seconds after that call. It is calculated that, in the circumstances of a 10 knot head wind component, the aircraft would have travelled 430 feet along the runway from the point of the heading call and would have achieved an IAS of 40.5 knots before the engines achieved full thrust.

If the aircraft had accelerated with full thrust at brake release, it would have achieved a speed of 40.5 knots after travelling only 270 feet, and therefore it could accelerate from a standing start from a point displaced from the threshold 320 feet and still achieve the speed of 40.5 knots at the same point as it has been calculated to have been achieved in the rolling start case.

Similarly it was established that, with a zero headwind component, the equivalent standing start position would be 330 feet from the threshold.

The V_1 speed computed before commencing the take-off was 138 knots and the call of V_1 was recorded on the cockpit voice recorder. It is not known if the V_1 call was made precisely at the speed of 138 knots but for the purpose of this study this has been assumed. A post accident calibration check of the pitot static system established that the captain's airspeed indicator was reading 1 knot high at air speeds in the vicinity of the V_1 speed and this has been taken into account in the performance data calculations.

It has been calculated that, on the assumption that there was a 10 knot head wind component, the slope corrected distance travelled to reach V_1 from the equivalent standing start position was 4,615 feet and on the assumption of a zero head wind component it was 5,105 feet.

Transition Phase

The cockpit voice record and the sound spectrum analysis established that the engines remained at 110% N_1 for 1.3 seconds after the V_1 call at which time there was a sound of a compressor stall followed by a call from the flight engineer that there had been a loss of power.

The performance data indicates that, in this time, the speed would increase to 140.5 knots and the distance travelled in the 1.3 seconds would be 300 feet in the case of the 10 knot head wind and 330 feet in the case of zero head wind.

The cockpit voice recorder analysis established that the throttles were brought to the idle position 1.6 seconds after the sound of the compressor stall. The mid-point of this period was arbitrarily selected as the effective recognition point and, if the crew reacted in accordance with the certification transition delay times to set the aircraft in the full braking configuration, it is reasonable to assume that the aircraft continued to accelerate from the bird strike to recognition, i.e. for 0.8 seconds, and then decelerated in accordance with the Boeing Company data. On this basis, the speed at recognition was 142.7 knots and the distance travelled from bird strike to recognition was 180 feet in the 10 knot head wind case and 190 feet in the zero head wind case.

Deceleration Phase

On the assumption that crew reaction times were the same as certification transition delay times in the sequence of actions to the actuation of speed brakes and that there was a further transition time of 3.13 seconds from speed brake actuation to achieving full reverse thrust, it is calculated that stopping distances from a speed of 142.7 knots would be, with brake only, 3,400 feet in the case of a 10 knot head wind and 3,850 feet in the case of a zero head wind and, with brakes and reverse thrust, 2,800 feet for a 10 knot head wind and 3,100 feet for zero head wind.

At Appendix A - Fig. 2 is a drawing which shows the runway, the bird carcasses, the wheel marks and the final position of the aircraft. For comparison there is shown, at Case A, the position where the aircraft would have come to rest on the basis of a theoretical accelerate/stop manoeuvre. It is assumed in this example that the aircraft gross weight was 309,560 lb, there was a head wind component of 10 knots and the runway was level. It was also assumed that the aircraft was stationary at the runway threshold and that the brakes were released at full engine thrust, that engine failure occurred at the selected V_1 of 138 knots, that recognition was immediate and that transition to deceleration was achieved in the certification delay times of brake application occurring 0.391 seconds after V_1, throttles cut 1.368 seconds later and then, after a further 1.967 seconds, speed brakes actuated. On these assumptions it is calculated that the total distance travelled by the aircraft before coming to rest would be 7,830 feet measured from the runway threshold and if reverse thrust were used during the deceleration the total distance would be 7,310 feet.

At Appendix A - Fig. 2 are also presented two cases which summarise the results of calculations in this study and are based on the conditions and circumstances of this accident; but one case assumes the existence of a head wind component of 10 knots and the other assumes that there was a zero head wind component. Both cases have taken into account the runway slope, the loss of effective use of runway arising from the rolling start from a side entry onto the runway, the loss of effective use of the runway caused by the aircraft rolling whilst power was progressively applied and the excess speed beyond that of V_1 before the decision to abandon take-off. Both cases have also taken into account the effect of reverse thrust in the deceleration phase. In the case with a 10 knot head wind component, the total distance is 8,215 feet and with a zero head wind the total distance is 9,055 feet; both distances being measured from the southern threshold of the runway.

2 - ANALYSIS

There are two main elements in the circumstances of this accident. Firstly, the aircraft struck seagulls and sustained a power loss which prompted the Captain to abandon the take-off and, secondly, the aircraft could not be stopped within the confines of the runway.

The examination of the aircraft and the testing of the engines and other components provided no evidence of any deficiencies or malfunctioning which could have affected the performance of the aircraft during the acceleration or deceleration phases of the abandoned take-off. There is evidence that birds were struck during the take-off roll at a time co-inciding with the power loss experienced in Number 2 engine, that birds or pieces of birds were ingested into three engines and that some of the damage sustained by Number 2 engine was consistent with damage from bird ingestion. Although the aircraft struck at least 11 birds, there is no evidence that the operation of the aircraft was affected other than in respect of Number 2 engine. Until the bird strike, the engines operated satisfactorily and the evidence of the flight crew is corroborated by the information derived from analysis of the cockpit voice recorder tape. There was evidence of loss of power in Number 2 engine but it is known that, during the deceleration phase, all engines achieved 110% N_1 and all EPR readings were "well up". It appears that Number 2 engine would have been capable of delivering substantial and possibly full power subsequent to the bird strike but the Captain would not have known whether the power loss indication pointed to a permanent power degradation or to a momentary power loss.

The examination and testing of the braking system indicated that full braking capability was available and wheel marks on the runway support the view that full braking was achieved.

The investigation did not disclose any deficiencies or malfunctioning of the aircraft which could have contributed to the accident and all facts indicate that the take-off was a completely normal operation conducted by a crew who were experienced and competent.

There are circumstances under which an aircraft may abandon a take-off and be brought safely to a stop within the confines of the runway and this accelerate/stop performance of an aircraft is one of the several take-off requirements with which an aircraft type must demonstrate compliance when undergoing type certification procedures. The Boeing 707-321B type aircraft was certificated under Federal Aviation Regulations, Part 25 - Airworthiness Standards : Transport Category Airplanes.

The accelerate/stop distance can be defined as the sum of the distances necessary to accelerate the aircraft from a standing start to V_1 speed and to come to a full stop from the point at which V_1 is reached assuming that the critical engine fails at V_1. The speed of V_1 can be defined as the speed at which, if an engine failure occurs, the distance to continue the take-off to a height of 35 feet will not exceed the useable take-off distance, or the distance to bring the aeroplane to a full stop will not exceed the accelerate/stop distance available.

An important aspect of this investigation was therefore concerned with, firstly, comparing the accelerate/stop performance achieved by this aircraft with calculated performance based on certification test performance data adjusted and modified for the particular circumstances and conditions of this take-off, and then considering the factors which could have contributed to the achieved performance.

The Boeing Company performance information indicated that the distance which would be travelled by an aircraft in an accelerate/stop manoeuvre, in the planned circumstances of this take-off but using the actual gross weight, was a total of 7,830 feet and with the use of reverse thrust it would be reduced to 7,310 feet. The length of Runway 34 at Sydney is 8,900 feet and although the gross weight of the aircraft on take-off was limited by the runway length available, this limitation was not because of an accelerate/stop performance requirement but was because of other take-off performance distance requirements. The take-off performance charts for this aircraft type indicate that, at the flight planned weight in the forecast conditions, the accelerate/stop distance requirement would be 8,070 feet. The distance covered in the abandoned take-off was 9,460 feet which is grossly in excess of the calculated distance, particularly as it is known that full reverse thrust was applied until the aircraft came to rest.

Before the take-off was commenced, the V_1 speed was computed as 138 knots and the engine compressor stall occurred 1.3 seconds after the Captain called V_1. Although it could be argued that, as the V_1 speed had been reached, the take-off should have been continued, it is interesting to note that the Federal Aviation Agency Approved Flight Manual for the aircraft type states that "when an engine failure occurs the take-off is normally refused when the failure is recognised prior to V_1 and is normally continued when it recognised after V_1. At V_1 the take-off may be either continued or refused". On the same subject the Pan American aircraft operating manual states "in actual operations a specified value of V_1 speed for any particular take-off conditions should not be considered as inerrant. Manual data for acceleration stopping distances are based on ideal runway conditions and corrections for wind and gradient are empirical and arbitary. Therefore a decision to continue or stop in the event of engine failure to take-off must be a matter of pilot judgement".

The Captain, although stating that the abort decision was based on his observation of a loss of power on only one engine, also stated that he was aware that the aircraft was being struck by a number of birds at the time that he made the decision to abandon the take-off. It is impossible to establish the thought processes which resulted in the Captain abandoning the take-off after passing V_1 but the possibility of a multiple engine failure may well have influenced him consciously or subconsciously. It was fruitless pursuing this aspect further in the investigation as the Captain's recollection of the sequence of events was that he abandoned the take-off following a loss of engine power occurring shortly after the aircraft had reached 100 knots. Having regard to the circumstances of the occurrence and to the guidance material provided in the operating manuals, the pilot's action in abandoning the take-off appears reasonable and the speed of the aircraft at the time the take-off was rejected did not in itself result in the aircraft over-running the runway. The decision to reject the take-off after the aircraft had passed V_1 speed, however, must remain as the prime factor in the circumstances leading to this accident.

In considering possible reasons for the aircraft not stopping in a lesser distance than 9,460 feet, the various factors which may contribute to accelerate/stop performance were given values, where possible, in terms of distance. In some cases it was possible to eliminate the factor from further consideration.

The possibility that the runway surface did not have an adequate friction co-efficient was considered but the investigation established that the quality of the surface was satisfactory and this possibility was rejected as a contributory factor.

Although Runway 34 is regarded as level for normal operational considerations, there are some variations in its gradient and the performance study considered the data provided in the elevation profile of the runway and its possible effect in the circumstances of this accident. It was calculated that the effect of the slope, when compared with a level runway, would be to reduce by 25 feet the total distance used by the aircraft.

The gross weight of the aircraft at the time of the accident was assessed as being 6,800 lb in excess of the flight planned weight and performance calculations indicate that this excess weight contributed 200 feet to the total distance actually travelled by the aircraft. Since the flight crew were not aware of the true gross weight of the aircraft the V-speeds were selected for flight planned weight and consequently were lower than those appropriate for the actual weight of the aircraft. This aspect had no effect on the development of the accident and it is concluded that the overloading did not in itself result in the aircraft over-running the runway.

In considering the distance used in the acceleration phase, the finding of the performance study was that the adoption of a rolling start from the side entry to the runway and the technique of progressive application of thrust resulted in the effective point of commencement of take-off being displaced to a point 320 feet from the runway threshold. This effectively reduced the take-off distance available by this amount as runway length requirements are based on measurement from the runway threshold and do not make allowance for manoeuvering the aircraft for either a standing start or for a rolling start from a side entry.

Although the performance analysis has assumed that the V_1 call was made at precisely 138 knots IAS, the possibility exists that the call was delayed and it is of significance to note that, had the call been made at 140 knots, the total distance travelled would have been increased by 290 feet. This possibility is considered further at a later stage in this analysis. Although the crew computed the V_1 speed as 138 knots, the information provided in the aircraft operating manual indicates that, with accurate interpolation, the selected V_1 speed would be 140 knots.

The cockpit voice recording indicated that the engines remained at 110% N_1 for 1.3 seconds after the V_1 call, at which time the compressor stall occurred, and it has also provided some information regarding the time sequence of actions by the pilot during the transition to the deceleration phase. There is, of course, no record of the timing of the vital action of application of wheel brakes nor is there a record of when the speed brakes were extended although the evidence does tend to suggest that this action was carried out in its correct sequence. Some measure as to the reaction of the pilot during this critical phase of the accelerate/stop manoeuvre can be gained by comparison with the certification transition delay time of 0.391 seconds from engine failure to wheel brake application and 1.759 seconds from engine failure to throttle cut. The time taken by the pilot to cut throttles from the time of engine failure was 1.6 seconds and, in this respect, the pilot's reaction time was very good.

The use of reverse thrust is not included in certification testing but information provided by the Boeing Company has specified an elapsed time of 6.856 seconds for implementation of full reverse thrust from engine failure. In this accident the cockpit voice recording indicates that reverse thrust was achieved 8.25 seconds after engine failure but it is noteworthy that the time taken to achieve full reverse thrust is governed not only by the pilot's actions but by the time taken to release the throttle interlock which is controlled by the speed of operation of the mechanical components of the reversers of each engine.

The possibility that there may have been a delay in the application of the wheel brakes compared with that demonstrated in the certification test data is also considered further at a later stage in this analysis.

Although precise timing of the sequence in which the deceleration devices were brought into effect cannot be established, the evidence indicates that maximum deceleration was achieved reasonably quickly and was maintained until the aircraft came to rest.

One variable factor of significance was wind velocity. The performance study has considered the effect of a 10 knot head wind component compared with a zero head wind component and it is calculated that the zero head wind component would add an additional 990 feet to the overall accelerate/stop distance required. A head wind component of 10 knots was used in the pre-take-off computations. The anemometer trace indicates that the head wind component could have varied between 2 knots and 9 knots and this wind variation must be retained as a possible explanation of part of the excessive distance travelled by the aircraft. The possibility of encountering a lesser wind than forecast is envisaged in take-off performance charts as they are required to incorporate accountability for only 50% of the reported head wind.

The location of bird carcasses and wheel marks on the runway is shown in Fig. 2, Appendix A, and has provided a basis for assessing conformity of the physical evidence with some significant events in the two calculations of performance. The location of the carcasses cannot be taken as precise evidence of the point of occurrence of the bird strikes as the birds may have been thrown a considerable distance by impact but, with this reservation, they do provide some evidence of the area in which the bird strikes occurred.

The accelerate/stop performance case based on an assumed 10 knot head wind component (Appendix A - Fig. 2, Case B) shows that the compressor stall, the position of which was established in time relationship to the V_1 call, occurred well before the position of bird carcasses on the runway and also indicated an unreasonably long delay between the decision to abandon the take-off and the commencement of the wheel marks. In addition, the total stopping distance required was much shorter than indicated by the runway marks and the aircraft should have stopped within the confines of the runway. On the other hand, in the zero head wind case, the compressor stall occurred just after the location of the first bird carcasses, the wheel marks commenced 620 feet after the assumed point of engine failure recognition, and it would be expected that the aircraft would come to rest 200 feet beyond the end of the runway. The total distance required in this case was 9,055 feet measured from the threshold of the runway compared with the actual position of the aircraft at 9,460 feet. This reconstruction is closer to the evidence established in respect of the actual occurrence and supports the view that the head wind component was significantly less than forecast.

The analysis has given values, in terms of distance, to a number of factors which could have been significant to the excessive distance travelled by the aircraft. These are summarised as follows :-

(a) a rolling start, side entry to the runway and progressive application of take-off thrust would increase the distance by 320 feet;

(b) the delay, beyond V_1, of the decision to abandon the take-off would increase the distance by 690 feet;

(c) a decay in the head wind component would increase the distance up to a maximum of 990 feet at zero head wind component;

(d) the use of reverse thrust would decrease the distance by 750 feet;

(e) the runway slope would decrease the distance by 25 feet.

It was also determined that, because of loading in excess of the flight planned gross weight, the overall distance travelled by the aircraft was increased by 200 feet.

The above values in distances do not, even taken together, provide an explanation for the amount of over-running which occurred, but there are two other factors. Firstly, the possibility of a delay in the call of V_1 and, secondly, a delay in the application of braking.

The calculations were based on the assumption that the Captain called V_1 at precisely 138 knots and the subsequent engine failure recognition speed was established from the time relationship of that call and the events recorded in the cockpit voice recorder. The total accelerate/stop distance is affected very significantly by recognition speed and had the V_1 call been made at say 140 knots the total distance travelled by the aircraft would have been increased by 290 feet. The flight data recorder read-out does not assist in resolution of the actual airspeed of the time of the V_1 call as there is evidence that the recorder was under-reading.

It is not possible to determine, in time sequence, precisely when the brakes were applied but the possibility that there was a delay in braking gains some support from the fact that the observed tyre marks commenced 620 feet after the assumed engine failure recognition point. This would represent a delay in the application of brakes of about two seconds in the zero head wind case with a V_1 call at 138 knots and a recognition speed of 143.7 knots IAS. The certification transit delay times provide for brake application to be made 0.391 seconds from the time of engine failure recognition and 1.368 seconds before the throttles are cut. While the need for immediate brake application is vital, the technique of applying brakes as the first step even before throttle cut, is one which is contrary to normal practice as related to a deceleration phase. In the landing roll which is, of course, the deceleration phase most usually experienced by pilots, normal technique is to close the throttle, actuate the speed brakes and then, after reverse thrust has been selected, commence application of brakes. Whether or not a pilot, in the split second timing of an abandoned take-off, can be expected always to make the conscious mental effort to act with his feet in advance of or even at the same time as acting with his hands, is a matter for conjecture.

It is therefore concluded that a number of factors resulted in this aircraft over-running the runway. Firstly, the decision of the pilot to discontinue the take-off being made after the aircraft achieved V_1. Secondly, the loss of effective runway length due to the employment of a rolling start and progressive application of thrust. Thirdly, the possibility that there was a delay in the calling of the V_1 speed is one which has not been resolved but the possibility remains. The fourth factor is the matter of the reaction time in the application of full braking, and here the physical evidence of the runway markings suggests there may have been a delay in the application of brakes. The fifth factor is the effect of overloading which resulted from a defective hydrometer. Finally, there is the effect of a reduction in head wind component at the beginning of the take-off roll or during the accelerate/stop manoeuvre, which would have increased significantly the overall distance travelled by the aircraft.

The employment of reverse thrust, which is not taken into account in the certification accelerate/stop data for the aircraft, was effective in the particular circumstances of this accident and reduced the compounded effect of the other factors.

There is no one factor which, in itself, would have caused this accident but, following the decision to abandon the take-off after V_1 and with the effective runway length reduced by the employment of a rolling start with progressive application of thrust, it then only required the other factors to combine adversely to result in the aircraft failing to stop within the confines of the runway.

3 - CONCLUSIONS

1. The flight crew were properly qualified for the flight.

2. The aircraft was airworthy.

3. The aircraft was inadvertently loaded 6,800 lb in excess of the flight planned weight, primarily as a result of use of a defective hydrometer.

4. During the take-off roll, and shortly after V_1 speed had been attained, the aircraft struck seagulls and Number 2 engine sustained a compressor stall as a result of bird ingestion.

5. The take-off was abandoned after V_1 but the over-run was not inevitable.

6. All engines developed full reverse thrust during the deceleration.

7. The aircraft and its systems were capable of normal operation.

8. The effective point of commencement of take-off was displaced some 320 feet from the threshold as a result of the rolling start technique employed from a side entry to the runway together with progressive application of thrust.

9. The head wind component encountered by the aircraft was significantly less than that forecast and that used in the take-off computations.

10. The increased gross weight of the aircraft resulted in the aircraft travelling 200 feet further than it would have travelled had it been loaded as planned.

11. The crew actions in the abandoned take-off procedures were timely in respect of throttle closure, application of reverse thrust and actuation of speed brakes but the evidence indicates that there may have been a delay in application of wheel brakes beyond that delay assumed in the accelerate/stop certification performance calculations.

12. The probable cause of the accident was that, in the circumstances of an abandoned take-off, the aircraft could not be brought to a stop within the nominally adequate runway length because of an error in the calculation of load, a reduction in wind velocity from that forecast and the use of rolling start and braking techniques which would not ensure most effective use of the available runway length.

FIG. 1. DECELERATION PATH OF THE AIRCRAFT

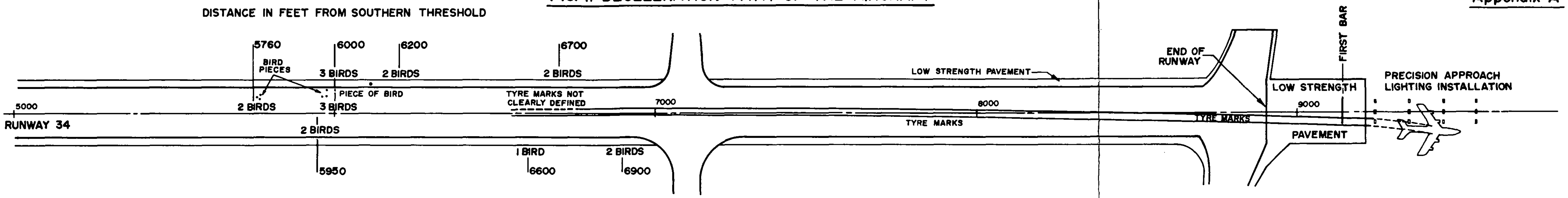
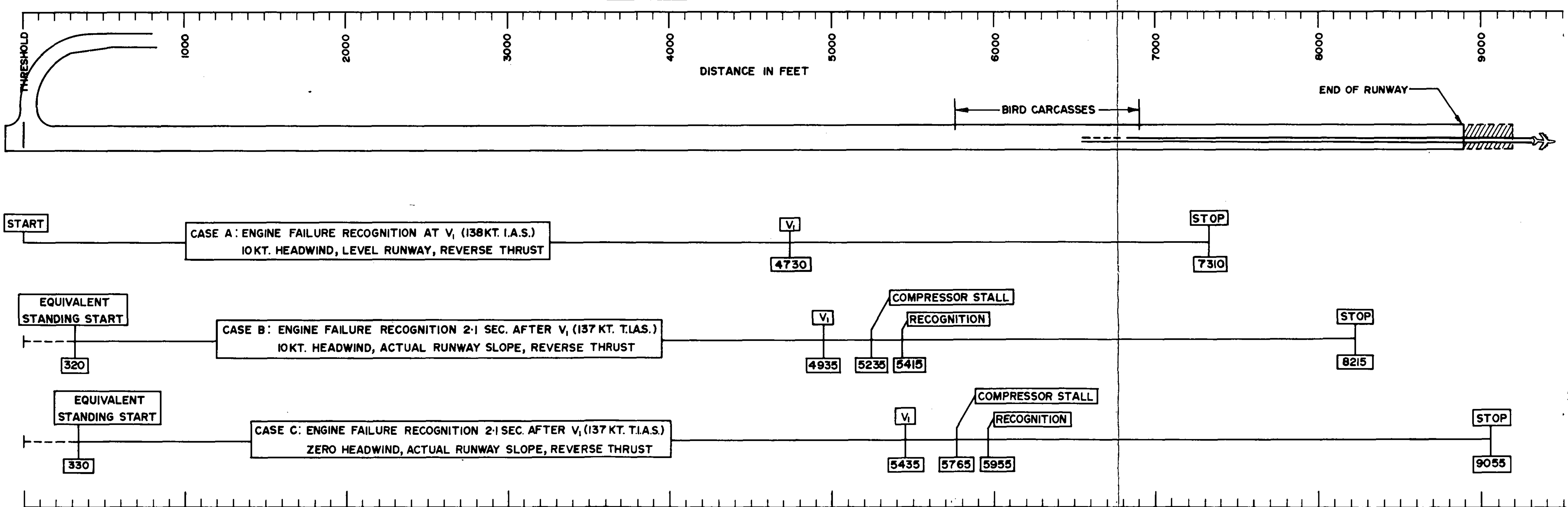


FIG. 2. PERFORMANCE COMPARISONS



ACCIDENT TO BOEING 707-321B AIRCRAFT N892PA

SYDNEY (KINGSFORD SMITH) AIRPORT, AUSTRALIA

1ST DECEMBER, 1969

COCKPIT VOICE RECORD

Transcript of readable communications between 0757:08.8 and 0759:08.9 GMT.

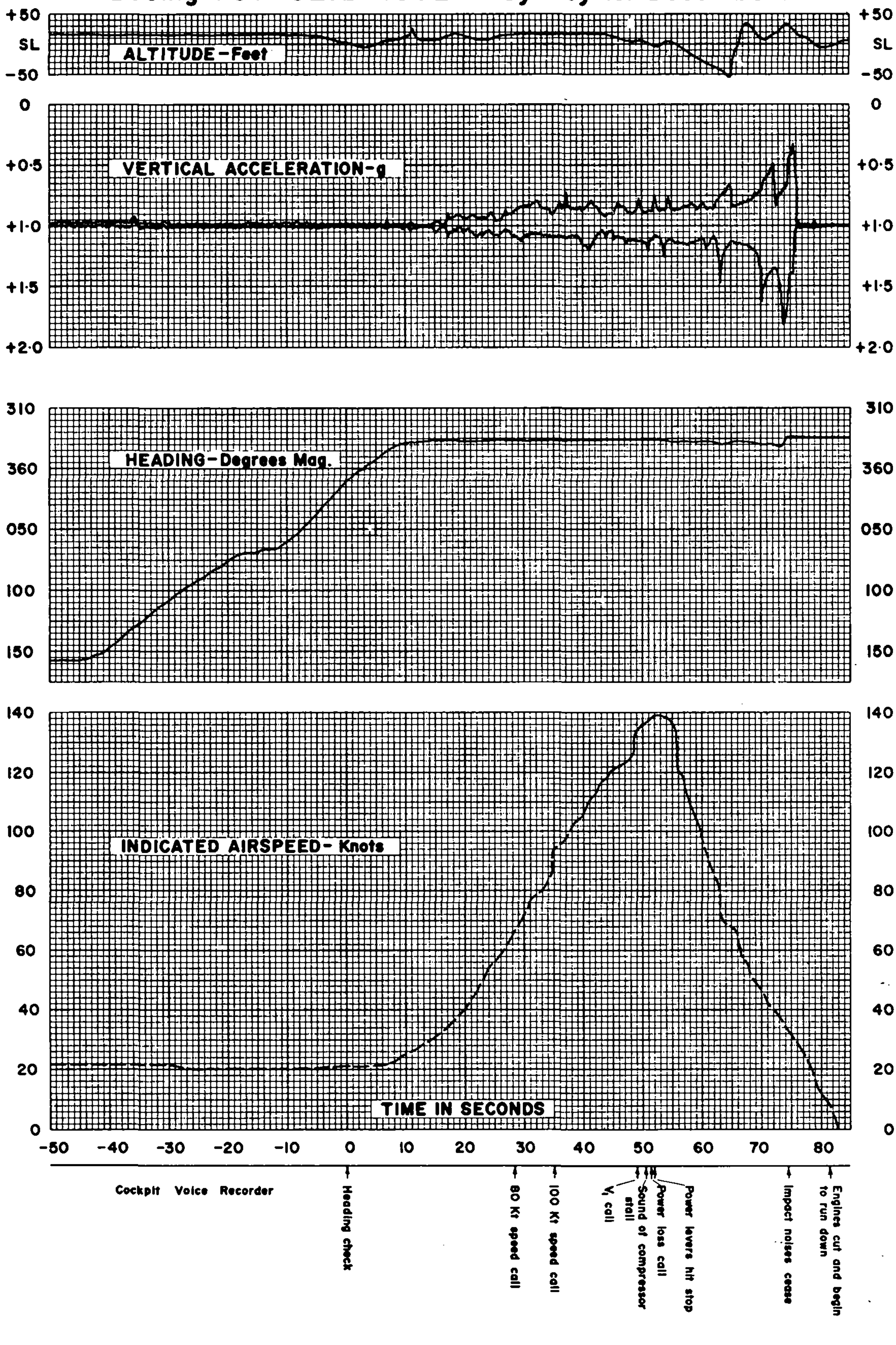
The abbreviations used are :-

CH 2/3	=	Captain's and First Officer's (F/O) jack boxes
CAM	=	Cockpit area microphone
P/A	=	Public address system

GMT	SOURCE	PERSON	TEXT	ELAPSED SECONDS
57:08.8	CH 2/3	Tower	Clipper Eight One One radar departure, turn right heading zero five zero, maintain three thousand, clear for take-off.	
57:16.8	CH 2/3	F/O	Zero five zero, maintain three, Clipper Eleven clear for take-off.	
57:23.8	CAM	Captain	Check list!	
		Flt. Eng.	Anti skid?	
		Captain	Is on.	
		Flt. Eng.	Speed-brake handle?	
		F/O	Forward.	
		Flt. Eng.	Stabiliser-trim?	
		F/O	Set.	
		Flt. Eng.	Wing flaps?	
		F/O	Fourteen, indicating and green light.	
		Flt. Eng.	Gyro-compasses (Query in voice)	
57:39.5		F/O	Is on .. Zero One Zero .. Now!	00.0
		Flt. Eng.	The take-off checklist is complete.	
57:44.5			(The sound of power being applied)	05.0
57:47.8		F/O	Take-off thrust! (Call for)	08.3

GMT	SOURCE	PERSON	TEXT	ELAPSED SECONDS
57:53.2	CAM		(Peak of power sounds)	13.7
57:55.7		Captain	Don't push down so .. quite so hard.	16.0
		F/O	O.K.	
		Captain	Just .. just enough to keep it from pounding	
58:07.0		Flt. Eng.	Powers good!	27.5
58:07.7		Captain	Eighty! Your steering	28.2
58:14.2		Captain	One hundred!	34.7
58:28.5		Captain	Vee One!	49.0
58:29.8			(Sound of compressor stall - "cough No. 1")	50.3
58:30.4			(Sound of compressor stall (?) - "cough No. 2")	50.9
58:30.5			(Sound of engine/s running down).	51.0
58:30.7		Flt. Eng.	Got - loss of power!	51.2
58:31.4			(Sound of power levers hitting stops)	51.9
58:34.4			(Sound of reverse thrust noise starts)	54.9
58:38.7			(Sound of full reverse thrust)	59.2
58:45.4			(Start of impact (or compressor stall?) noises).	65.9
58:46.7		F/O	(Non-pertinent word)	67.2
58:49.5			(Loudest impact sound)	70.0
58:53.9			(Impact noises cease)	74.4
58:54.0		Captain	Let's get out of the airplane	74.5
		Flt. Eng.	Get out of the airplane all!	
58:56.9			(Window opens)	77.4
59:01.0			(Engines cut : begin run down)	81.5
		F/O	Cut 'em!	
59:05.0	CAM	Captain	Cut everything!	85.5
59:06.1	P/A	Stewardess	Would you please take your seats	86.6
59:08.9			(End of Recording)	89.4

Graph of Flight Data Recorder Readings
Boeing 707-321B N892PA Sydney 1st December 1969



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