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IMPERIAL ETHIOPIAN GOVERNMENT
CIVIL AVIATION ADMINISTRATION

REPORT ON

EAST AFRICAN AIRWAYS SUPER VC-10 ACCIDENT AT ADDIS ABABA ON APRIL 18 1972

PUBLISHED BY
IMPERIAL ETHIOPIAN GOVERNMENT
CIVIL AVIATION ADMINISTRATION
P. O. Box 978, ADDIS ABABA
February 1, 1973.

The Administrator,
Civil Aviation Administration,
Addis Ababa.

Subject: **East African Airways SVC-10 Accident Investigation.**

Sir,

I have the honour to submit herewith, the final report on the subject accident which occured on April 18, 1972, *at Addis Ababa.*

I am pleased to report that, the full investigation was carried out in the spirit of the Chicago Convention and in accordance with the Standard and Recommended Practice outlined in Annex 13 *to that Convention. The States of Registry and Manufacture, in response to the invitation accorded by this Administration, have both appointed accredited representatives who arrived at the scene shortly after the accident occured. There after, these representatives as well as those representing the operator and manufacturers have fully participated in the investigation, including the approval of the final draft report.*

I am glad to acknowledge the co-operation and assistance received from all participants, and in particular, my appriciation goes to Mr. P. J. Bardon, the Accredited Representative of the State of Manufacture who followed up the entire work with keen interest, from the begining to the end and had made most valuable contributions.

I also wish to thank the manufacturers, namely, the British Aircraft Corporation and the Dunlop Company for providing their expertise and facilities for the detailed technical examinations and performance analysis which were so vital to the investigation.

Sincerely,

Bekele Serbessa
Chief, Office of Safety
(Investigator-In-Charge)

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REPORT ON THE ACCIDENT TO EAST AFRICAN AIRWAYS SUPER VC-10, 5X-UVA ON APRIL 18, 1972, AT ADDIS ABABA

GENERAL INFORMATION

Aircraft: Vickers Super VC-10 Type 1154, Registration 5X-UVA

Engines: Four Rolls Royce Conway 550B

Owner: British Aircraft Corporation

Operator: East African Airways Corporation

Crew:			
	Commander	— Captain J.P. VALE	Killed
	Co-pilot	— First Officer R.P.H.BOTTO	Killed
	Navigator	— Navigation Officer F.D.MACNABB	Killed
	Flight Engineer	— Flight Engineer B.A.H. TWIST	Killed
	Purser	— P.MWICIGI	Injured
	Chief Steward	— JOCIPHARES MALOLE	Killed
	Senior Stewardess	— YAERI KAGEZI	Injured
	Steward	— BAKAMAZE	Killed
	Steward	— MWANGI	Killed
	Steward	— R. AYIRO	Killed
	Stewardess	— M. FADHIL	uninjured

Passengers: 35 Killed
13 Injured
48 Uninjured

Place of Accident: Haile Selassie I International Airport, Addis Ababa

Date and Time: 18 April 1972, at 0940 hours

Note: All times in this report are GMT

SUMMARY

The aircraft was taking off from Addis Ababa for a flight to London via Rome. Just prior to reaching Decision Speed (V_1), a nose wheel tyre was punctured by a light aircraft jacking pad, lying on the runway. The crew immediately initiated the appropriate abandon take-off procedure but were unable to stop the aircraft before it reached the end of the runway. The aircraft dropped heavily on the lower ground and broke up on impact. A severe fire ensued and the aircraft was completely destroyed. 43 passengers and crew were killed; 15 were injured and 49 were unhurt.

The report concludes that the accident was due to a partial loss of braking effort arising from the incorrect reassembly of part of the braking system, as a result of which the aircraft could not be stopped within the runway and stopway distance remaining.

1. —INVESTIGATION

1.1 History of the Flight

The aircraft was operating East African Airways Flight EC-720 to London via Addis Ababa and Rome. It had departed from Nairobi at 0655 hours on 18 April, 1972 in the charge of the crew later concerned in the accident. The flight to Addis Ababa was uneventual and the aircraft landed there at 0823 hours, at an all up weight of 103,394 kgs. On landing, the aircraft was observed to roll the whole length of runway 07, in order to make use of the turning pad at the end.

During the transit stop at Addis Ababa, a quantity of freight was off-loaded together with 40 passengers. Fifteen passengers joined the flight, bringing the total on board at departure to 107 persons, including 11 crew members. The aircraft was refuelled to 50,000 kgs of fuel, resulting in an all up weight (at the time of taxi) of 132,738 kgs. Whilst the aircraft was on the ramp at Addis Ababa the attention of the flight engineer was drawn to a leak of hydraulic fluid from the No. 1 rear main wheel (that is the left outer rear position). After the system had been pressurised, the flight engineer considered that the leak was small enough to be acceptable for the flight to London, where the defect could be rectified. No other unserviceabilities were reported.

Start up clearance was given at 0921 hours and the aircraft taxied out at 0927 hours via the eastern taxi-way for take-off on runway 07. The Tower advised the aircraft that the wind was 5 knots and variable in direction.

At 0932 hours, as the aircraft was backtracking to the take-off point, the pilot advised the Tower that there was a number of dead birds on the runway, and that the aircraft had hit one of them on landing. It was requested that these birds be removed before the aircraft took-off.

The Tower agreed to do this and accordingly despatched a fire truck (call sign Addis One) at 0935 hours.

The aircraft continued to backtrack down the runway and turned in the pad at the end. It then lined up on the runway and stopped a short distance from the threshold. At 0938:40 hours, the Tower cleared the aircraft for take-off. The pilot acknowledged and shortly afterwards at 0939:15 hours, he called "rolling".

The ground run appeared to outside observers to be normal for just over half the runway length, though two of the surviving passengers stated afterwards that they thought the initial acceleration was poor.

Shortly after the aircraft had passed the midpoint of the runway and was near where it would normally have been expected to take-off, a loud bang was heard. This was subsequently established as being caused by the right hand nose wheel tyre bursting. The effect of this was to cause a severe vibration to be felt on the flight deck and a "loss of control" according to a brief statement made by the flight engineer after the accident shortly before he died.

Almost immediately after the nose wheel tyre had been heard to burst, the nose of the aircraft was seen to rise momentarily and then come down. The engines were also throttled back at about this time, and were subsequently heard to go into reverse thrust.

The aircraft continued down the runway, veering slightly to the right as it did so. White smoke was observed to be emanating from the wheels at this stage. A few seconds later, a second bang was heard, and this was subsequently found to be due to the failure of No.1 rear main tyre. Just before the aircraft reached the end of the runway, it veered slightly to the left and ran approximately parallel with the centre line. After crossing a storm drain located at the end of the runway at right angles to the centre line, the aircraft became momentarily airborne as it left the lip of the embankment on which the 60 m stopway was laid. As it did so, the left outer wing of the aircraft struck a steel lattice tower forming part of the approach lighting system to runway 25. This ruptured No. 1A fuel tank and the released fuel promptly ignited. Sixty metres beyond the end of the runway the aircraft fell heavily on to the lower ground 10.6 m below the runway level. It broke up immediately on impact and after sliding a short distance, came to rest and caught fire.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	8	35	—
Non fatal	2	13	—
None	1	48	

1.3 **Damage to Aircraft**

The aircraft was destroyed.

1.4 **Other damage**

The top section of a steel approach lighting tower near the threshold of runway 25 was damaged.

1.5 **Crew Information**

a) **Flight Crew**

Captain J.P. Vale, aged 42, held a valid East African Airline Transport Pilot's licence, endorsed for the command of Super VC-10 aircraft.

The latest available record of Captain Vale's flying hours, dated 28 October 1971, showed that up to that time he had flown a total of 8,769 hours, of which 752 hours were on the Super VC-10 aircraft. It is not known how much of this was in command time, as official records did not show. His personal flying log book is presumed to have been destroyed at the time of the accident. Captain Vale last underwent a competency check ('B' Check) on 14 April 1972, in the VC-10 simulator and was assessed as "Very Good". This check included an Abandoned Take-Off procedure.

Captain Vale was last medically examined on 27 October 1971 and pronounced as fit for the renewal of his ALTP licence. During the 30 days preceding the accident, he had flown a total of 31 hours. His rest period prior to the flight to Addis Ababa was 26 hours.

First Officer R.P.H. Botto, aged 26, held a valid East African Senior Commercial Pilot's licence (SCPL), endorsed in Group 2 for the Super VC-10. He had flown a total of 2,744 hours as at 12 January 1972, the latest date for which records were available, and of this, 640 hours were on the SVC-10. Mr. Botto passed a combined instrument rating and competency check ('A' Check) on 12 January 1972.

He was last medically examined on 11 January 1972 and pronounced fit for the renewal of his SCP licence. During the 30 days preceding the accident, Mr. Botto had flown a total of 62 hours. His rest period prior to the flight to Addis Ababa was 4 days and 8 hours.

Navigating Officer F.D. MacNabb, aged 45, held an East African Flight Navigator's licence, which was valid for all types of aircraft. On 5 March 1972, records showed that Mr. MacNabb had flown a total of 20,653 hours. He was last medically examined on 3 March 1972 and pronounced fit. He passed a Completency check on 24 March 1972. Mr. McNabb had been off duty for 7 days prior to the flight to Addis Ababa.

Flight Engineer B.A.H. Twist, aged 34, held a valid East African Flight Engineer's licence endorsed for the Super VC-10 aircraft. His total flying time when it was last officially rendered on 11 October 1971 was 3,577 hours, of which 1,513 hours were on the SVC-10. Mr. Twist Was last checked in emergency procedures on the VC-10 simulator on 5 January 1972, and was assessed as "very good". His last flight check on the route was in August 1971. In addition to his Flight Engineer's licence, Mr. Twist also held a valid East African Commercial Pilot's licence, endorsed for the Piper PA-28 aircraft. He was last medically examined for this licence on 23 March 1972 and for his Flight Engineer's licence on 11 October 1971, and in both cases he was pronounced fit. Mr. Twist had been off duty for 5 days and 22 hours prior to the flight to Addis Ababa.

b) **Cabin Crew**

Competency checks were carried out on the cabin staff on the following dates:

Purser:	Paul Mwicigi	25 March 1972
Chief Steward:	JocipharesMalole	8 February 1972
Snr.Stewardess:	Yaeri Kagezi	26 January 1972
Stewardess:	Miriam Fadhill	4 April 1972
Steward:	Bakamaze	14 March 1972
Steward:	Mwangi	9 October 1971
Steward:	Ayiro	21 October 1971

1.6 **Aircraft Information**

a) The aircraft was constructed by the British Aircraft Corporation during the year 1966. It went into service with the East African Airways Corporation that same year, having been issued with both a United Kingdom and an East African Certificate of Airworthiness. At the time of the accident the latter Certificate was valid until 29 September 1972.

The aircraft had been maintained in accordance with an approved maintenance schedule. It was last inspected on 9 March 1972 and a Certificate of Maintenance was issued, which was valid at the time of the accident.

The aircraft had flown a total of 18,586 hours, 409 of which were since the issue of the Certificate of Maintenance and 2,003 since the renewal of the Certificate of Airworthiness.

b) **Weight and Balance**

The load sheet for the flight to Rome was examined together with the passenger and cargo

manifests. These had been prepared by the Ethiopian Airlines on behalf of the operator in accordance with normal practice. The Basic Weight and Index figures used on the load sheet were checked against company records and found to be correct. It was also noted that the aircraft was last weighed on 29 September 1969. A revision was made on 26 January 1971, increasing the Basic Empty Weight by 149 kgs.

The number of passengers on the load sheet was 97 as against the actual total of 96. This was due to the off-loading of one passenger after the load sheet had been prepared.

The weight of the 97 passengers recorded on the load sheet had been incorrectly calculated as 6,466 kgs, whereas the correct figure was 6,531 kgs. This was a negligible error and in any case was compensated for by the off-loading of one passenger.

According to the refuelling record, 9,641 gallons of fuel was uplifted at Addis Ababa, bringing the total fuel on board to 50,000 kgs.; including an allowance of 600 kgs for taxi fuel. Allowing for two small errors in the computation of passenger baggage and cargo weight together with the passenger weight error referred to above, the actual weight at take-off was calculated to have been 132,138 kgs. as opposed to 132,043 kgs. as recorded on the load sheet.

This excess of 95 kgs. is considered to have been a negligible amount and of no significance in the context of the accident.

The distribution of load was checked against the Company's Balance Chart and the centre of gravity was found to be within limits. From the same Chart it was determined that the tailplane setting required for take-off was minus 5.2; this had been correctly recorded on the load sheet.

c) **Replacement of Brake System Components**

On 5 April 1972, a hydraulic leak from the t rear axle was noted, in consequence of which the associated hydraulic transfer coupling was changed together with the anti-skid units. On 7 April, the No. 1 rear tyre burst on landing following brake application. This was thought at the time to be due to a defect in the No. 1 rear anti skid unit and it was accordingly changed. There is no record of any further changes having been made to this part of the braking system.

1.7 Meteorological Information

A weather observation made shortly after the accident gave the following information:

Surface wind	170 degrees, 9 knots
Temperature	21° C
Dew point	9° C
Weather	Nil
Cloud	1/8 cumulo-nimbus base 750 m
	6/8 cumulus base 900 m
Visibility	7-10 km.
QNH	1023.9 mbs

Since 0800 hours the surface wind as measured at the airport meteorological station had been reported at half-hourly intervals as follows:

0800	190 degrees, 8 knots
0830	Calm
0900	170 degrees, 5 knots
0930	170 degrees, 8 knots

At the time the aircraft called for taxi-clearance, the Tower reported that the surface wind was 5 knots and variable in direction.

The accident occured during daylight hours.

1.8 Navigation Aids

Navigation aids were not a factor in this accident.

1.9 Communications

All the recorded tapes in the Air Traffic Control were played back after the accident for the relevant period and it was confirmed that the local tower frequency of 118.1 MHZ was the only one used by the aircraft. All communications between the aircraft and the tower were normal. The aircraft first called at 0921 hours, requesting taxi clearance, and the last transmissions from the aircraft were identified as being made by Captain Vale.

Communications between the tower and the fire truck, Addis One, were made on 121.9 MHZ. The crew of this fire truck, who had been engaged in clearing the dead birds from the runway, saw the aircraft abandon its take-off and disappear off the end of the runway. As it did so they called ATC for assistance. The time of this call was established to be 0940:23 hours.

1.10 Aerodrome and Ground Facilities.

The Haile Selassie 1st. International Airport has a single runway, 07/25. Over a period of months, the runway had been resurfaced with asphalt and extended to 3,700 m with additional 60 m stopways at each end. This work was completed by 7 April 1972, when it was announced by NOTAM HAAB A053 that the runway was

fully operational. However, the NOTAM did not give any details regarding the revised runway length, and up to the time of the accident, this information had not been officially promulgated.

In order to accommodate the additional length, it had been necessary to raise the level of the ground at each end of the runway, where it otherwise slopes down. In the case of runway 07, the up-wind end had been built up to a height of approximately 10.6 m and at the foot of this embankment and on the extended centreline of the runway, had been erected a steel lattice tower forming part of the approach lighting system to runway 25. The top of this tower was level with the surface of the runway and it was positioned approximately 24 m off the end.

The overall slope of runway 07 was 0.1% downhill, though in fact it sloped up slightly to the mid-point and then sloped down 0.29% to the runway end.

At the time of the accident the runway surface was dry. The runway surface is normally inspected once each day at 0300 hours, and records showed this inspection to have been carried out on the morning of 18 April.

The air traffic control log showed that there had been 37 aircraft movements prior to the departure from the ramp of 5X-UVA. One of these movements involved a locally based Cessna 185 aircraft which took-off at 0455 hours. It was subsequently established that it was from this aircraft that the jacking pad probably fell.

1.11 Flight Recorder

a) The flight recorder, located in the rear of the ventral freight compartment, was recovered intact and despatched to The British Aircraft Corporation for read-out under the supervision of the UK Accidents Investigation Branch. It was a United Data Control unit, Model FB—542, part number 100550-1, serial number 2361.

b) Examination of the foil showed that all parameters had been recorded and could be clearly read with the exception of the datum line which was faint, and the airspeed trace, which was unusually thick. All the parameter datums were found to be within specified tolerances. The initial read out of the flight recorder traces was made using nominal calibrations. It was found that the accuracy of the magnetic heading and normal acceleration traces were good and needed no further correction. The accuracy of the pitch trace was also good but a correction of 1 degree had to be applied to compensate for the aircraft's ground attitude. The altitude trace was found to be inaccurate and it was suspected that the recording mechanism itself was faulty. No reliance could therefore be placed on the altitude plot.

Considerable difficulty was experienced with obtaining a credible airspeed plot from the recorder read out. The intial read out showed unusually low speeds and this together with the poor quality of the trace itself led to an attempt being made to check the accuracy of the read out against previous flights where the conditions were known. This work showed that the recorded speeds were generally 10 knots too low at the low speed end.

A detailed calibration was then made which showed that there had been a change since the previous calibration made in August 1971. There were also sings of hysteresis in the recording mechanism. A further calibration was accordingly made using a constantly varying input of pressure to simulate as closely as possible the accelerate stop case. This calibration was successful in showing up the amount of hysteresis.

When this calibration was applied to the recorded airspeed values, the results were found to be more credible than hitherto and it was felt that they were the most accurate that could be achieved in the circumstances.

However, it is still possible that the final speed plot may be in error due to unknown changes that may have occurred in the flight recorder itself as a result of the accident. Nevertheless, though the absolute accuracy of the recorder airspeed values must always remain in doubt, there was no evidence to justify its outright rejection. It is considered, therefore, that the airspeed trace as plotted, represents a fair though approximate record of the aircraft's indicated airspeed above 80 knots. This is the minimum speed on which reliance can be placed with this type of recorder.

All five parameters are shown plotted against time in seconds at Appendix A.

The start of the take-off run was identified as occurring during the first 8 seconds as given by activity on the pitch and heading traces and more precisely by activity on the airspeed trace after 4 seconds.

Abnormal activity between 51 and 51½ seconds on the magnetic heading trace on the recorder foil itself (not reproduced on the plot) suggested that the unit was subjected to heavy vibration at that point. It is considered that this was most probably coincident with the nose wheel tyre burst.

The period for which the nose of the aircraft was raised is shown clearly by the pitch trace,

though the precise interval of time that the nose wheel itself was clear off the ground could not be established due to uncertainty as to the exact amount of oleo extension involved.

At 74 seconds, the pitch trace shows the nose wheel leaving the end of the runway followed ½ a second later by the main wheels. Impact with the lower ground occurred at 76 seconds as given by normal acceleration and pitch attitude.

1.12 **Wreckage**

1.12.1 **Distribution of Wreckage and Marks on the Runway. (see Appendix B).**

The first tyre marks attributable to 5X-UVA were found on the runway surface 2,159 m from the commencement of the runway and 0.7 metres to the right of the centre line. These marks clearly indicated that the right hand nose wheel tyre had burst at that point. Lying nearby was found a steel component of channel section 9 by 4 by 8 cms, which was subsequently identified as a jacking pad used on Cessna 185 aircraft. A clear impression on the runway surface to a depth of 2.3 cms. exactly matched the profile of the jacking pad and this impression could be seen 11.5 metres before the tyre burst point and in line with it. Subsequently, an examination was made of the remnants of the right hand nose wheel tyre of 5X-UVA, and one of these was found to have a cut in the tread which also exactly matched the profile of the jacking pad.

Marks made by the burst tyre as it revolved could be seen to run parallel to the centre line for a distance of 131 m, where they ceased momentarily before reappearing 15 m further on. The marks then continued for a further 15 m when they again ceased and they did not reappear for another 295 m. Marks made by both nose wheel tyres could then be seen in one continuous line until the end of the runway. The marks made by the left hand nose wheel tyre indicated that a severe nose wheel shimmy had occurred from the time that the nose wheel tyres had last remade contact with the runway.

The first marks attributable to the main wheels could be seen 333 m down the runway from the point of nose wheel burst, and these marks had been made whilst the nose wheel was clear of the runway surface and 108 m before it remade contact. The marks made by the main wheels were light in intensity for the first 68 m but thereafter became heavy and continuous for the remaining 1200 m of runway and stopway.

183 m beyond the point where the mainwheel tracks first became apparant, there was an increase in intensity of the marks made by the left main gear and at this point there were signs of a tyre having burst. This was later established as being the No. 1 rear tyre.

The main landing gear tracks showed that the aircraft had continued parallel to the centre line for a short distance and then had veered slowly to the right. When it was approximately 300 metres from the end of the runway and on the right hand edge, the aircraft had turned slightly left so as to parallel the centre line of the runway once more and it continued on this heading until it passed over the end.

As the aircraft passed the end of the runway it crossed a stone lined drain, 1 m wide and 0.5 m deep, located at right angles to the runway centre line. Both undercarriage bogies were damaged on impact with the drain and No. 2 rear and No. 3 front tyres burst at this point; the former becoming detached from its wheel in the process.

The aircraft became momentarily airborne as it left the end of the runway where the ground drops steeply away. As it did so, the left outer mainplane struck the steel lattice approach lighting tower, breaking off the outer slat and leading edge section. It also ruptured No. 1A fuel tank and severed electrical cable looms in the leading edge of the wing. Pieces of structure from this portion of the wing and tank were found between the base of the tower and where the left mainplane finally came to rest. There was also evidence from scorch marks on the ground that fuel released from the ruptured tank was on fire and this had trailed the aircraft to the final impact area.

The aircraft fell heavily on the soft lower ground 60 m beyond and 10.59 m below the end of the runway, the initial impact being taken by the main landing gear. The aircraft broke up immediately into three major portions namely the tail empennage with the engines attached; the centre section and wings; and the forward part of the fuselage. The tail section came to rest 44 m beyond the initial impact point whilst the remainder of the aircraft slid a further 44 m down the slope. In the latter stages of the ground slide, the nose section swung round to the right and came to rest facing back towards the airfield. A severe fire broke out almost immediately and this eventually consumed the forward and centre fuselage sections togather with the left wing and right wing root. The tail unit was extensively scorched but was otherwise relatively undamaged.

1.12.2 **Examination of the Wreckage.**

With the exception of the braking system, no evidence was found of pre-impact mechanical

or technical malfunction nor were there any signs of pre-impact structural damage. A detailed examination of the wreckage was made and the results of this are summarised below.

a) Configuration:
Nose and main landing gear—down and locked.
Flaps — 20 degrees (take off position)
Slats — Out (take off position)
Spoilers — Out to fullest extent.
Tailplane incidence — Between 5 and 6 degrees nose up.
Nos. 1 and 4 engine thrust reversers
— Reverse thrust position

b) Aircraft attitude at impact:
— Laterally level with no slip or skid, and slightly nose down.

c) Main landing gear — Both legs had been torn from the structure on impact. The left gear was subsequently damaged severely during the ground fire. The right gear was undamaged by fire, having been thrown clear of the main wreckage by the force of the impact. The condition of the tyres on this gear were good. The No. 3 front tyre had burst on contact with the storm drain and the remaining tyres had deflated due to the operation of the fusible plugs.

d) Flight deck — This area had been completely burnt out and yielded no useful evidence.

e) Engines — Nos. 2, 3 and 4 engines were relatively undamaged but were extensively blackened by smoke from the ground fire. All three could still be freely rotated and it was considered that each of them would have been capable of delivering full power up to the moment of impact. No. 1 engine had ingested some hard object which had severely damaged the LP compressor. It was apparent that this had occurred during the break up of the aircraft on impact. There was no other evidence to suggest that this engine would not have been capable of delivering full power before the accident.

1.12.3 **Examination of the Brake System.**

The brake assemblies and associated anti-skid units were examined initially at the Company's maintenance base at Nairobi and then later sent to the United Kingdom for detailed examination by the manufacturer under the supervision of the UK Accident Investigation Branch. It was found in the course of this latter examination that all eight brakes had been serviceable during the aircraft's attempted take-off but, that only five of them had been used to their individual maximum energy limit of 42 million ft. lbs during the deceleration phase. The remaining three brakes were found to have absorbed lesser amounts of energy, as follows:-

No 4 front	— 29 million ft lbs
No 1 rear	— less than 19 million ft lbs
No 2 rear	— less than 19 million ft lbs

Thus the total energy which had been absorded by the brakes during the deceleration phase of the accident sequence was between 239 and 277 million ft. lbs, that is, between 70-80% of the design maximum.

A further examination was therefore made of the three brakes which had absorbed less energy than the other five to account for the loss in braking efficiency.

In the servo unit serving no. 4 front brake, it was found that a restrictor pack had been incorrectly assembled with the result that the flow of fluid to the brake could have been less than normal. In incipient skid conditions, this reduced flow would have resulted in a slower recovery of brake pressure after it had been relieved by the anti-skid unit. In consequence, the brake would have been off for a longer period than would normally have been the case. It is considered that it was at least partly for this reason that the No. 4 front brake absorbed less than maximum energy.

The No. 1 rear brake had absorbed negligible kinetic energy due to the locking of the wheel and bursting of the tyre early in the accident sequence. The reason for this was two fold. Firstly, it was found that the transfer unit in the left rear axle had been installed in the reverse of its correct position. The effect of this was to cross couple the anti-skid units and brakes in the left rear axle, so that the No. 1 rear brake was being controlled by No. 2 rear anti-skid unit and the no. 2 brake was being controlled by no. 1 rear anti-skid unit. This in itself would not have been significant provided that both anti-skid units were serviceable. However, it was found that the No. 2 rear anti-skid had been totally inhibited by the installation of a rubber ring at the point where a hydraulic coupling was fitted to one end of the transfer unit. From marks on the ring, (which was not part of the installation) it could be seen that it had blocked the four ports of the anti-skid valve block. This would have prevented the No. 2 rear anti-skid unit from relieving No. 1 rear brake pressure in a skid situation, thus causing the No. 1 rear wheel to lock and its tyre to burst.

When the no. 1 rear wheel locked, the No. 1 rear anti-skid unit would have sensed the skid but, in this instance (because of the cross coupling) would have caused the brake pressure to No. 2 rear brake to be relieved. The pressure should

have been restored automatically after 4 to 5 seconds. Had it been so the energy absorbed by No. 2 rear brake would have been considerably more than in fact was the case. It would appear, therefore, that after the pressure to this brake had been relieved by No. 1 anti-skid unit, maximum pressure was not re-applied for the remainder of the accident sequence. No reason for this could be found. Not all components of this particular braking system were recovered.

1.13 **Fire**

a) Fire initially broke out when the left outer wing struck the approach lighting tower just after the aircraft left the runway. The effect of this impact was to rupture No 1A fuel tank and the released fuel was ignited either by sparks generated as a result of the wing hitting the tower or by arcing due to the disruption of electrical cable looms in the leading edge of the wing. There was evidence of burning on the ground from the point of impact with the tower to the final position of the left wing on the ground, indicating that the fire had trailed behind the aircraft for the whole distance. The left wing was subsequently almost entirely consumed by fire.

On impact with the ground, the aircraft broke into three major components, releasing most of the 50,000 kgs. of fuel on board. According to the statements of survivors, fire appears to have started almost immediately after impact towards the rear and underside of the main cabin. There the heat was described as being intense at floor level. Fire also broke out immediately after impact on the right side by the wing root. This prevented the emergency exits on that side being used. Fire eventually consumed the main cabin area, the forward fuselage, the left wing and the right wing root. The tail unit together with the engines were unburnt though extensively scorched.

b) The first fire truck on the scene was Addis One, which had been previously engaged in removing the dead birds from the runway prior to the aircraft's take-off. This reached the scene at 0942 hours. Other airport fire vehicles were despatched, the first ariving at 0944 hours and the others at some undetermined time later. From 1025 hours onwards, unts of the city fire service participated in fighting the fire. The last practice by the Airport Fire Services was on 4 March 1972, during which the Fire Crews practiced fire extinguishing and rescue drills. The Fire Service equipment was inspected on the day of the accident at 0300 hours. The part played by the Airport and City Fire services and the type and quantity of media applied to the fire is the subject of specialist investigation.

1.14 **Survival Aspects**

a) **Rescue**

In the main, the evacuation of the aircraft by the passengers and crew was self effected. Considerable selfless assistance was rendered by members of the cabin staff and also some of the passengers, some of whom died as a result of their efforts in this respect when they would have otherwise survived. The evacuation was facilitated considerably by the fortuitous fracture of the left forward fuselage, allowing relatively easy egress. Had it not been for this fracture casualties may well have been greater, as the left emergency exits were jammed by impact damage and the right side exits were blocked by fire.

b) **Survival**

It appears that the majority of those on board survived the impact, but some subsequently succumbed to the effects of fire. Those who managed to get clear of the aircraft to the left side found their way blocked by a barbed wire fence. This forced most passengers and surviving members of the crew to walk down the slope alongside two main streams of fuel flowing from the aircraft. This fuel subsequently caught fire, trapping a number of people, believed to be about ten in number.

1.15 **Performance Calculations**

a) **Scheduled Performance**

The Operator's airfiled Regulated Take Off Weight (RTOW) chart for Addis Ababa was no longer valid at the time of the accident since it related to the former length of the runway. The Generalised Take Off Chart was therefore used to check the aircraft's RTOW and field requirements appropriate to its last take-off.

In making these calculations, the following airfield data were utilised:

Runway 07

Take Off Run — Available (TORA)	— 3,700 m
Take Off Distance Available (TODA)	— 3,760 m
Emergency Distance Available (EMDA)	— 3,760 m
Slope Down	— 0.29%
Elevation (amsl)	— 7,625 ft
Temperature	— 21 degrees C
Wind Component at the time of take-off	— 1½ knots Tail

From this data the Balanced Flied Length required for the aircraft's actual take-off weight of 132,138 kgs. was found to be 3,300 m and the maximum permitted take-off weight (RTOW) was found to be 135,800 kgs.

It should be emphasised that the above calculations, which were post accident, were based on the actual wind and temperature conditions prevailing at the time of take-off and merely serve to confirm that the aircraft was not overweight for operation using the full length of runway 07. Since the crew would not have known the precise values of wind and temperature that they would encounter on take-off, their pre-take off calculation of RTOW would have had to be based on assumed or predicted values. Thus, it could be expected that there would normally be a difference between the two values of RTOW. Such is the case in this instance, where the pre-take off RTOW recorded on the Load Sheet was 132,400 kgs. i.e. 3,400 kgs less than the RTOW based on actual values.

However, this is a large discrepancy and it is considered that it cannot be wholly explained in terms of differences between predicted and actual values of wind and temperature. It is more likely that the difference was due to the crew basing their calculations of RTOW on a runway length which was less than the actual length of 07 but more than the old length. Consideration of the Balanced Field length required for the RTOW recorded on the Load Sheet suggests that the crew may have allowed for only half the actual runway extension in the interests of erring on the safe side since no revised runway length had been promulgated.

As regards the runway slope the crew may have used in their calculations, it appears most unlikely that they would have used the value of 0.29%. This is because they would have assumed most probably that the slope of the new 07 runway was close to the slope of the old one, and may have used the value of 0.15% as indicated on the Company's RTOW chart for Addis Ababa. In fact the slope of the old runway 07 was 0.296% as calculated in accordance with the provisions of Annex 14 of the ICAO Agreement. The resulting difference in RTOW and V_1 due to the use of a 0.15% slope would have been approximately 400 kgs. and 2 knots, which for all practical purposes was negligible and had no bearing on the cause of the accident.

The V_1 and V_R values that were most probably calculated by the crew using the Generalised Take Off Chart and a slope of 0.15% would have been 135 and 145 knots respectively. With the 0.29% slope applied, the V_1 as given by the Flight Manual would have been between 128 — 140 knots and V_R would have been 144 knots for the aircraft's actual take off weight.

b) Calculation of the Speed Envelope and Maximum Speed Attained.

Calculations were made to check the extent to which the evidence obtained from runway marks, brake examination and the flight recorder were mutually consistent. In making these calculations, certificated Flight Manual data was used, together with other relevant aircraft and runway data and that full reverse thrust was available. Also taken into account was the fact that the total load of the aircraft was taken on only seven wheels during the greater part of the deceleration phase following the failure of the No. 1 rear tyre early in the sequence.

It was found, as a result of these calculations, that the various parts of the evidence were mutually consistent with the exception of the speed as given by the flight recorder, which was shown to have been generally 10 knots too low. The results of the performance calculations are shown graphically at Appendix 'C' and are summarised as follows:-

1. The take-off roll was commenced 123 m in from the beginning of the runway.
2. The nose wheel burst occurred at an airspeed equivalent to 135 knots when the aircraft had travelled a distance of 2013 m.
3. The decision to abandon the take-off was most probably taken 1.9 seconds later when the airspeed was equivalent to 140 knots and the distance gone was 2170 m.
4. The maximum airspeed reached by the aircraft was equivalent to 143 knots.
5. The airspeed of the aircraft as it left the end of the runway was equivalent to 67.6 knots (assuming zero wind).

From these calculations, it was also deduced that the maximum braking effort was approximately 61,000 lbs., that is approximately 70% of the established Flight Manual certificated value. To achieve the performance calculated, it would appear that the brakes would have absorbed 215 million foot pounds of kinetic energy against certificated maximum of 340 million. Allowing for most adverse factors, calculations show that had full braking been available, the aircraft could have been stopped within the distance remaining at the time the decision to abandon the take off was implemented.

1.16 **Other Information**

1.16.1 **Relevant Extracts from the Company Flying Manual**

(a) **Abandon Take-Off Procedures**

When the ATC tape recording of the R/T conversation on 118.1 MHZ was played back, the voice of the pilot making the transmission from the aircraft was positively identified as that of Captain Vale.

Assuming that normal Company procedures were being followed, this indicated that the co-pilot was handling the aircraft from the right hand seat from the time it left the ramp until at least when the emergency occurred, if not beyond that point. The relevant sections of the Flying Manual supporting this conclusion were contained in Section 3-2-1 page 8, paragraph 12 and on page 2 of the same section, paragraph 2 (4).

In the event of an emergency, the Manual states that control will remain with the co-pilot unless the captain decides to take over control. In this event, the co-pilot reverts to his normal duties.

In the event of the take-off being discontinued whilst under the control of the co-pilot, the executive order 'Abandon' may be given by either the captain or the co-pilot. The co-pilot will close the throttles and apply full brakes. The captain will select full spoilers and apply reverse "Ihrust as necessary. The captain will then call, "I have control" and take over control of the nose wheel steering and the brakes. (Reference Section 3-2-1 page 5, paragraph C).

The following paragraph D states that in the event of an emergency at or after V_1, no action will be taken until the captain gives the command which will not be below 400 ft.

In Section 3-5-1 page 5, paragraph I entitled "ABANDONED TAKE-OFF", it is stated, the basis of calculation of stopping distances from V_1 includes the assumption that only one thrust reverser will be available. The paragraph goes on to say, maximum retardation can be affected by continous application of anti-skid braking and the use of reverse thrust, which should be applied as soon as possible. The brakes must be considered as the primary means of retardation.

(b) **Brake Cooling Times**

In Section 2-4-1 page 2. under the heading BRAKE COOLING TIMES, it is stated that "if the scheduled stopping distances are to be achieved in the event of an abandoned take-off, the brakes must be cool enough at the start to absorb the required amount of energy". The information as to the correct cooling time assumes two cases, one of which is relevant to this accident, namely, "To allow the next take-off to be abandoned at maximum V_1 after a normal landing".

In the accompanying table, the longest brake cooling time was given as 57 minutes and this relates to a higher landing weight and higher take-off weight than was the case with 5X-UVA. The time interval between the aircraft landing and commencing taxi was in fact 64 minutes.

(c) **Despatch of Aircraft with Unserviceable Equipment.**

Part 5 of the Company Flying Manual details those items of equipment which can be accepted as unserviceable at the commencement of a flight, subject to the aircraft commander's discretion. One of the items so listed was any one of the eight anti-skid units with which the aircraft was fitted.

1.16.2 **Relevant Extracts from the Super VC-10 Maintenance Manual.**

Instructions for the installation of an anti-skid unit were contained in section 32-40-35 of the Super VC-10 Maintenance Manual current at the time of the accident. These instructions did not include any explicit provision for the functional testing of the equipment following installation.

2 — ANALYSIS AND CONCLUSION

2.1 **Analysis**

The aim of this analysis is to consider the most significant features of the evidence that has been obtained with a view to establishing the following:-

1. The maximum speed attained by the aircraft as registered on the pilot's instruments and how this related to the actual speed of the aircraft over the ground.
2. The distance remaining to the end of the runway from the point where the aircraft reached its maximum speed.
3. The effect of deficiencies in the braking system.

The analysis will then examine the actions of the crew in dealing with the emergency.

(a) **Speed of the Aircraft**

In considering the maximum speed reached by the aircraft, a clear distinction has to be made

between the speed as registered on the pilot's instruments (and on the flight recorder) and the actual speed of the aircraft over the ground. Normally the two speeds can be directly related after due allowance has been made for the effects of altitude, temperature and surface wind, together with position and instrument error corrections.

In the case of 5X-UVA, it was found that the speed as given by the flight recorder (which would normally be the same as that registered on the pilots' instruments) was substantially less than that which the aircraft had undoubtedly achieved according to performance and other calculations. Though initially this was thought to be due to errors within the recorder itself, it was found that the disparity still existed after further calibration work had ironed out most of the errors. Though a small residual error may still remain, no adequate reason could be found to explain the discrepancy between recorded and predicted speeds. It was of interest to note however, that the 8 knot differential between the two maximum speeds was equivalent to a 10 knot tailwind component for a period of approximately 20 seconds. It was not impossible, in the meteorological conditions prevailing at the time, that there was a gust of this magnitude and duration at the relevant time. Certainly, an indication of mildly gusty conditions was given by the jerky quality of the airspeed trace throughout the take off run. However, as there was no positive evidence as to the actual behaviour of the wind over the runway, the difference between recorded and predicted speed cannot be ascribed to these effects with certainty.

In conclusion therefore, it is considered that the best assumption that can be made as regards the speed history of the aircraft is that the flight recorder speed plot represents the minimum airspeed that the pilots could have read on their instruments during the acceleration phase and that the predicted performance line at Appendix 'C' represents the maximum. On this basis, the indicated airspeed when the nose wheel burst must have been between 120 and 135 knots, and the decision to abandon the take-off was taken when the indicated airspeed was between 125 and 140 knots. Subsequently, the speed rose to a peak value of between 135 and 143 knots, which was equal to a ground speed of between 156-166 knots.

(b) **Position at which Maximum Speed was Attained**

The difficulty in establishing where on the runway the maximum speed was attained by the aircraft has already been mentioned. Logically, the aircraft must have reached its maximum speed somewhere between the point where the nose wheel burst, when it was still accelerating and the point where heavy braking marks were apparent on the runway, when the aircraft was decelerating. These distances were 2158 and 2560 m respectively from the beginning of the runway. Between these two points, it was positively established from marks on the runway that the nose wheel was off the ground, and that it had not come down again by the time heavy braking occurred. Though it was not known precisely where on the pitch trace of the flight recorder plot the nose wheel regained the runway, it must have been somewhere between 56 and 57 seconds. If the application of brakes was instrumental in pitching the nose wheel back on the runway, then (relative to the pitch trace) heavy braking most likely occurred at 56.2 seconds. If this is accepted, then it follows that if the indicated airspeed at that time was 143 knots (assuming the higher value) then this was most probably the speed of the aircraft when it was 1200m from the end of the runway (i.e. 2560 m from the beginning). Calculations have shown that it should have been possible to bring the aircraft to rest from this speed and within this distance given fully serviceable brakes and reverse thrust.

(c) **Condition of the Braking System**

The available braking effort shortly after the abandon take-off procedure had been implemented was approximately 70% of the certificated value. This was established separately by both performance calculations and detailed brake examination. Calculations positively established that this amount of braking effort was insufficient to bring the aircraft to rest within the runway and stopway distance remaining from the speed it was travelling at the time. The loss of braking effort was due to the bursting of the No. 1 rear tyre early in the accident sequence, the unexplained failure of the No. 2 rear brake to operate effectively and the partially reduced operation of the No. 4 front brake. The reasons for at least part of the loss of braking effort could be directly attributable to the presence of an alien seal found within No. 2 rear anti-skid system, reversed fitting of the left rear transfer tube and possibly from blockage arising from mis-assembly of part of the restrictor valve in No. 4 front brake system. In the event however, the installation of the transfer coupling in the reversed sense together with the presence of an alien seal in the No. 2 anti-skid system was significant only when braking to the level of anti-skid operation took place. Such a situation existed during a landing on 7th April, 1972 when No. 1 rear tyre burst. The diagnosis was a faulty No. 1 rear anti-skid unit which was changed and the aircraft returned to service with

both defects still present. There were no funtional checks for the system specified in the Maintenance Manual following the change of an anti-skid unit.

(d) **Nose Wheel Tyre Failure**

The reason for the nose wheel tyre failure was positively established as being due to penetration by the piece of steel channel section lying in the path of the aircraft 2147 m from the beginning of the runway. It was also established that this object, identified as a jacking pad used on Cessna 185 type aircraft, has been deposited on the runway 4 hours 40 minutes before 5X-UVA began its take-off run and had lain there unnoticed. This was not altogether surprising as the object was relatively small and unlikely to be seen other than by pure chance. The pad had been deposited long after the daily runway inspection and there was therefore, no possibility of it being discovered in the normal way. The area covered by the crew of the fire truck sent to clear the dead birds in the runway prior to the take-off of 5X-UVA did not include that in which the jacking pad lay.

(e) **Decision to Abandon Take-off**

There would seem to be no doubt that the decision to abandon take-off was taken solely as a result of the nose wheel burst and for no other reason. There was no evidence that the failure of the nose wheel tyre resulted in any other damage which could have given rise to a decision to abandon take-off. Whether or not the crew fully appreciated the true nature of the emergency is not known. The flight engineer stated that the vibration was severe and that there was also a "loss of control." It was not possible to clarify precisely what he meant by this, but clearly it suggests an alarming and confusing situation from which the crew could well have presumed the aircraft to be in a non-airworthy condition. In fact, as is now known, the aircraft could have been taken off and flown away safely but, this is not to imply the crew acted incorrectly, or even considered that they had a choice in the matter.

So far as can be ascertained, the nose wheel burst before the maximum V_1 (Decision) Speed of 140 knots was attained as given by the Flight Manual, and the decision to abandon the take-off was taken almost immediately. This was a perfectly proper decision for the crew to make, if they considered that the nature of the emergency was sufficiently serious. All the evidence points that the crew have implemented the decision to abandon the take-off very quickly. The distance between the nose wheel burst mark and the point where light braking was apparent was 333 m. At the ground speed the aircraft was travelling, say approximately 80 m/sec., this distance would have been covered in about 4 seconds. Within this time, the crew obviously recognised the emergency, took the decision to abandon take-off and, had taken the necessary actions by the end of the 4 second period. This indicates fairly positively that the crew's reaction time was well within that allowed for by scheduled performance criteria.

(f) **Despatch of Aircraft with one Unserviceable Anti-skid unit.**

There is no doubt that the crew were quite unaware of the actual condition of the brake system prior to the aircraft's departure from the ramp at Addis Ababa, particularly as regards to the state of the no. 2 rear anti-skid system. Therefore, the provisions of part 5 of the Company Flying Manual which allows a flight to be commenced with one unserviceable anti-skid unit were not applicable in this case. However, the wider implication of allowing the despatch of an aircraft with an unserviceable anti-skid unit are clearly relevant in the light of what happened to 5X-UVA. It would appear that the aircraft could have been despatched quite properly with the no. 2 rear anti-skid unit deliberately blanked off and in the event still been unable to stop from an abandoned take-off at V_1. It would seem that further consideration should be given to the question of permitting the deliberate despatch of aircraft with less than fully serviceable brake systems, particularly from airfields where the consequences of an overrun area are severe.

2.2 **Conclusions**

(a) **Findings**

1. The documentation of the aircraft was in order.
2. The aircraft had been properly loaded.
3. The crew were properly licensed and qualified to conduct the flight.
4. The aircraft was most probably being handled by the co-pilot from the right hand seat. This was in accordance with the provisions of the Company Flying Manual.
5. The right hand nose wheel tyre was punctured by a steel jacking pad lying in the path of the aircraft on the runway surface.

6. The crew took the decision to abandon the take-off when the speed of the aircraft was at or below the maximum V_1 and this decision was properly implemented.

7. The emergency distance available at the time the crew commenced the abandon take-off procedure was sufficient in which to stop the aircraft, given a fully serviceable braking system.

8. The No. 1 rear tyre burst shortly after brake application due to the lack of anti-skid protection. This was because the No. 2 anti-skid unit, to which the No. 1 brake had been inadvertently connected, had been inhibited by the presence of an alien seal.

9. The No. 4 front brake did not operate to the fullest extent possibly due to reduced hydraulic flow through an incorrectly assembled restrictor valve.

10. The reason that the No. 2 rear brake did not achieve full braking effort could not be determined due to fire damage and non-recovery of certain components of the system.

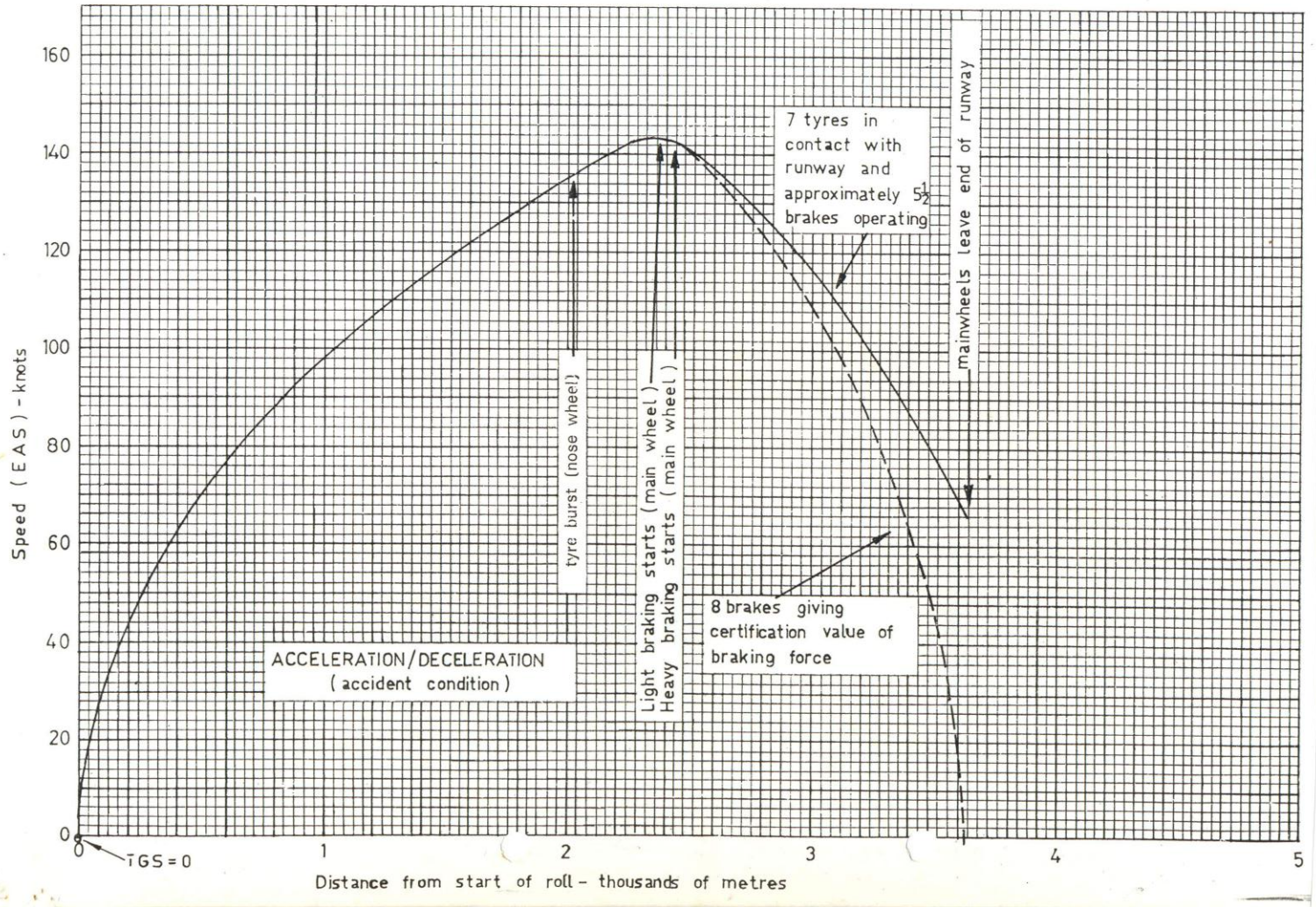
11. The resultant braking effort was insufficient to stop the aircraft within the emergency distance remaining at the time that the take-off was abandoned.

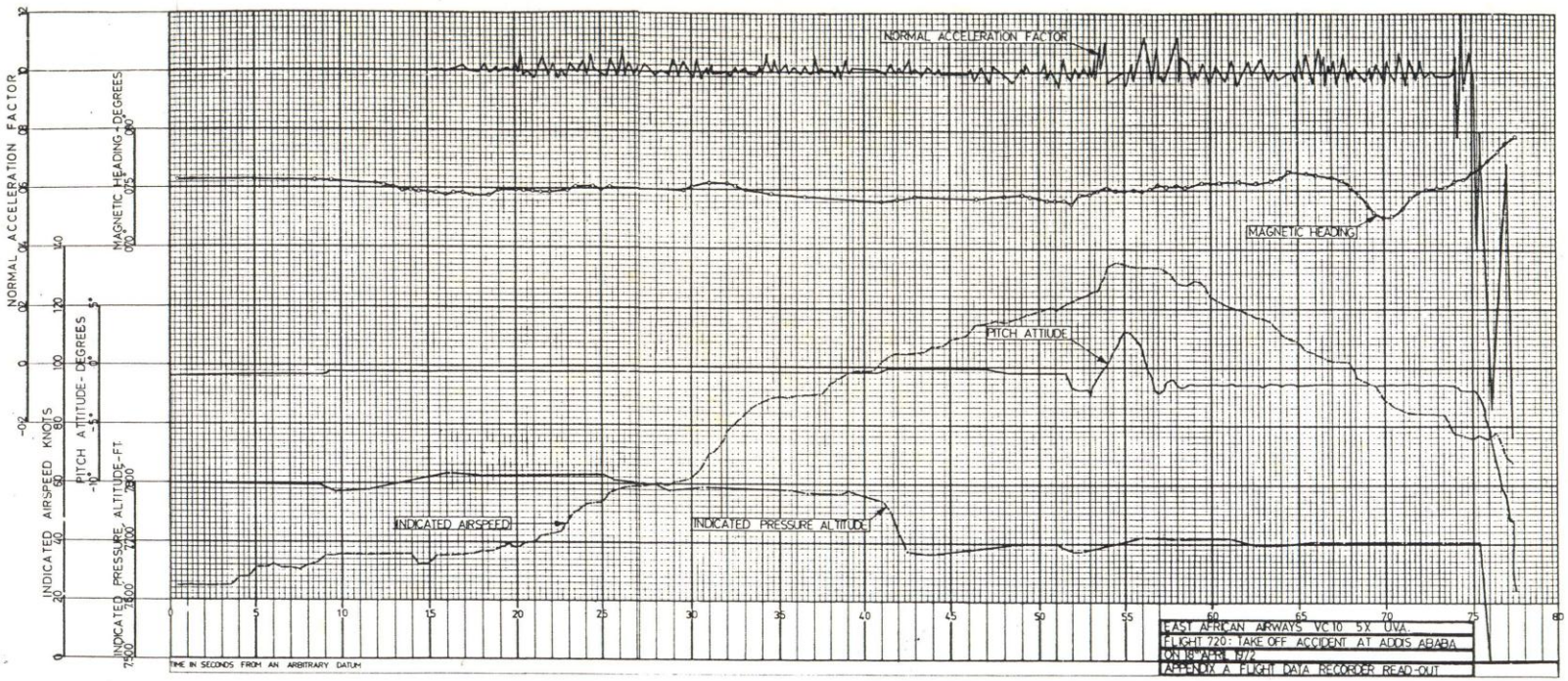
12. The aircraft had been maintained in accordance with an approved maintenance schedule. However, the functional test procedures specified in the maintenance manual in force at the time were insufficiently comprehensive for the purposes of checking the correct operation of the braking system following component changes.

(b) **Cause**

The accident was due to a partial loss of braking effort arising from incorrect re-assembly of part of the braking system, as a result of which the aircraft could not be stopped within the emergency distance remaining following a properly executed abandoned take-off procedure.

EAST AFRICAN AIRWYS SVC - 10
ACCIDENT AT ADDIS ABABA
ON APRIL 18 1972




NORMAL ACCELERATION FACTOR
MAGNETIC HEADING - DEGREES
PITCH ATTITUDE - DEGREES
INDICATED AIRSPEED KNOTS
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NORMAL ACCELERATION FACTOR
MAGNETIC HEADING
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TIME IN SECONDS FROM AN ARBITRARY DATUM
EAST AFRICAN AIRWAYS VC10 5X UVA
FLIGHT 720 : TAKE OFF ACCIDENT AT ADDIS ABABA
APPENDIX A FLIGHT DATA RECORDER READ-OUT