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Department of Transport
Australia

Air Safety Investigation Branch

ACCIDENT INVESTIGATION REPORT

Nomad N24 Aircraft Serial Number 10 at Avalon, Victoria, on 6 August 1976

Special Investigation Report 77-1

AIR SAFETY INVESTIGATION BRANCH

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Government Aircraft Factories Nomad N24 Aircraft Serial Number 10 at Avalon, Victoria, on 6 August 1976

The Secretary to the Department of Transport authorised the investigation of this accident and the publication of this report pursuant to the powers conferred by Air Navigation Regulations 278 and 283 respectively.

Prepared by Air Safety Investigation Branch

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Contents

Note 1: All times are Eastern Standard Time and are based on the 24-hour clock. Where applicable, seconds are shown using a six figure time group.

Note 2: Metric units are used except for airspeed and wind speed which are given in knots; and for elevation, height and altitude which are given in feet.

THE ACCIDENT

At approximately 1103 hours Eastern Standard Time (EST) on 6 August 1976 the pilot of Nomad N24 aircraft Serial Number 10 encountered control difficulty at a height of about 950 feet immediately after taking off at Avalon aerodrome. The aircraft entered a descending turn to the left through about 175 degrees and struck the ground. The pilot was killed; the occupant of the other pilot seat, an observer, sustained injuries which resulted in his death two days later; and the third occupant, the flight test engineer, was seriously injured.

1 FACTUAL INFORMATION

1.1 HISTORY OF THE FLIGHT

Nomad N24-10 was owned by the Government Aircraft Factories (GAF) and was the prototype of the N24 aircraft, a lengthened version of the previously certificated Nomad N22 type aircraft. For some months it had been engaged on test flying in the standard N24 production configuration in preparation for Department of Transport certification flight tests.

GAF were also conducting developmental work, in parallel with but separate from the N24 certification program, for a proposed N24A model which was to have an increased gross weight and configuration changes which included the availability of a 20 degree flap setting for take-off. As N24-10 was the only aircraft available it was being used as the test vehicle for both programs.

At the time of the accident N24-10 was engaged in the N24A development program, and the normal tailplane with part-span tabs had been removed and a modified tailplane with full-span tabs and trailing edge T strips had been fitted.

The purpose of the flight on which the accident occurred was to examine the effect of these tailplane modifications on the longitudinal stability of the aircraft in the 20 degree flap configuration required for the N24A model. It was intended that, after take-off, the aircraft would proceed to a designated flight test area where, at a safe altitude, the tests would be carried out. The aircraft was not to be flown at a speed in excess of 120 knots equivalent airspeed (EAS).

For the flight on which the accident occurred the aircraft carried the trade-plate registration VH-SUZ, and at 1033 hours the pilot telephoned Avalon Tower, discussed the weather and submitted a verbal flight plan. He was told that the wind velocity at the time was 240 to 260 degrees at 20 knots gusting to 35 knots and that there was 'a bit of weather coming through, the cloud to the south is about fifteen hundred and there's a shower over Geelong at the moment'. The pilot informed the tower that he planned to depart at 1045 hours for a 60-minute flight in N24-10, the flight to be conducted under the visual flight rules (VFR) in Restricted Area 326B (see Appendix A) at varying altitudes to a maximum of 10 000 feet. He nominated the fuel endurance as 300 minutes and indicated that the aircraft would take off from one of the grass strips on the eastern section of the aerodrome (see Section 1.10). Also he stated that it was his intention to 'go out and have a look and if it's no good come back and we'll give it a break for an hour or two'.

At 1051 hours the pilot of N24-10, using his personal radio callsign GAF ONE, contacted Avalon Tower by radio and advised that he had received the current aerodrome terminal information and was taxiing. The aircraft then taxied to the east–west grass strip.

At 1058 hours Avalon Tower advised N24-10 of the local weather and that there were aircraft reports of extensive cloud and build-ups to the south-west moving in a north-easterly direction. The pilot of N24-10 acknowledged this information and advised that he would attempt to operate in the northern half of Restricted Area 326B. At 1059 hours N24-10 requested an airways clearance and was cleared by Avalon Tower to operate in area R326B not above 10 000 feet.

At 1100 hours N24-10 notified that it was ready for take-off and the controller advised that there would be a short delay, which was due to other traffic landing on the runway. At 1100:23 hours N24-10 was cleared for take-off and an unrestricted climb.

The aircraft took off into the west from the grass strip and, immediately it became airborne, the pilot applied a series of 'push–pull' control inputs to the tailplane after which the aircraft commenced its initial climb. Data on the take-off and initial climb were obtained from the flight test recorder (see Section 1.11).

The aircraft climbed straight ahead in a normal manner and reached a height of about 950 feet when over or just past the runway. At this point three witnesses on the ground, who had observed the whole of the take-off, and who were located some 400 metres north of the aircraft's flight path and 600 metres east of the runway, observed the trailing edge of the aircraft's tailplane fluttering; one described it as being 'like a rag flapping in a strong wind', and he saw a dark object fall from the aircraft to the ground. At about this time the aerodrome controller, located in the control tower some 1250 metres south-east of the aircraft, saw it adopt a steep nose-down attitude and asked whether operations were normal. The pilot replied 'negative negative', and the aerodrome controller then initiated emergency procedures and the crash alarm was sounded.

The aircraft then turned left onto a southerly heading while still descending, and may have maintained this heading briefly before continuing to turn left onto an easterly heading. Just prior to contact with the ground, the left wing and the nose dropped, and after impact the aircraft rotated through 120 degrees in the horizontal plane and skidded rearwards for a distance of some 70 metres before coming to rest. An illustration of the flight path of the aircraft is shown at Appendix B.

The flight test engineer, who was seated in approximately the mid-cabin area of the aircraft during the flight, was unable to observe any cockpit instrument readings or any actions taken by the pilot. He stated that the take-off roll and lift-off were normal and that, after the pilot had exercised the tailplane with 'push–pull' control inputs, the landing gear and flaps were retracted and the aircraft was climbed towards the west apparently accelerating to normal climbing speed. Additionally he reported that he operated the trace recorder at high speed during the take-off and that he turned it off after the landing gear and flaps had been retracted. No abnormality was apparent to him until the aircraft reached a height which he estimated as 1000 to 1200 feet when a buzz type vibration occurred and the nose pitched down positively. He recalls that shortly after the onset of the vibration the pilot said 'I don't think we're going to make it'. The engineer then decided to abandon the aircraft, released his safety harness, and went to the parachute pack stowage. As he was about to remove his parachute pack from its stowage he heard the pilot say that he thought he had regained control, and at this time the nose-down pitch attitude reduced. He returned to his seat and refastened his safety harness. The aircraft then entered a descending turn to the left and the vibration continued intermittently until, at a height he estimated as about 100 feet, the pilot appeared to be no longer able to maintain any control and the aircraft side-slipped to the ground.

The duration of the flight from the commencement of the take-off roll until the aircraft struck the ground was about 1 minute 34 seconds.

The accident occurred during daylight at latitude 38° 02′ 28″ South, longitude 144° 28′ 12″ East.

1.2 INJURIES TO PERSONS

Injuries	Crew	Passengers	Others
Fatal	1	—	1
Non-fatal	1	—	—
None	—	—	

1.3 DAMAGE TO AIRCRAFT

The aircraft was destroyed by impact forces.

1.4 OTHER DAMAGE

A short section of post and wire fencing was demolished.

1.5 PERSONNEL INFORMATION

1.5.1 Aircraft

For flight test purposes the aircraft normally has a basic crew of a pilot and a flight test engineer. This crew may be supplemented as necessary by additional specialist personnel, depending upon the nature of the test to be carried out. The aircraft is equipped to be operated as a single-pilot aircraft and there is no requirement for personnel other than the pilot to be licensed.

On the flight on which the accident occurred, in addition to the basic crew, the Senior Designer Structures and Mechanical who, at the time of the accident, was also the acting Chief Designer of GAF, was on board the aircraft for the purpose of observing the effect of the modifications which had been carried out on the tailplane.

PILOT Stuart Graham Pearce—aged 39 years—left-hand pilot seat

Mr Pearce was a graduate of the Empire Test Pilot's School, Farnborough, U.K., and prior to being employed by GAF he had extensive test pilot experience in the Royal Air Force. His pilot licence was endorsed for a number of single and multi-engined aircraft types.

Licence	:	Senior Commercial Pilot Licence—valid until 31 October 1976
Ratings	:	Class One Instrument Rating—valid until 28 February 1977
Last medical examination	:	15 April 1976
Total pilot hours	:	4483
Total hours in command N22	:	1377
Total hours in command N24	:	73

FLIGHT TEST ENGINEER Philip Patrick Larcey—aged 36 years

Mr Larcey had been employed as a flight test engineer for the past 12 years during which time he had logged 2042 hours of flying experience in this role in a variety of aircraft. In addition he was a licensed pilot.

Licence	:	Private Pilot Licence—valid until 31 May 1978
Last medical examination	:	4 May 1976
Total pilot hours	:	approx. 360 (includes both aeroplanes and gliders)

OBSERVER David Roy Hooper—aged 47 years—right-hand pilot seat

Mr Hooper was a qualified aeronautical engineer. In addition he was a licensed pilot.

Licence	:	Private Pilot Licence—valid until 28 February 1977
Last medical examination	:	24 January 1975
Total pilot hours	:	approx. 2000 (includes both aeroplanes and gliders)

1.5.2 Air Traffic Control

An air traffic control unit is established in the Avalon Tower with provision for two operating positions, an aerodrome/approach controller and a co-ordinator. At the time of the accident both positions were manned by appropriately rated personnel; additionally a trainee air traffic controller was receiving instruction from the co-ordinator, and a Royal Australian Air Force air traffic controller was present in the tower on a familiarisation visit.

1.6 AIRCRAFT INFORMATION

The Government Aircraft Factories Nomad N24 is a twin-engined, high wing, light transport aircraft, powered by two Allison 250-B17B turbo-prop engines.

A Certificate of Type Approval had not yet been issued and consequently there was no requirement for Certificates of Registration or Airworthiness for N24-10. It was operating for the purpose of ferry and flight testing to an approved flight test program under the authority of a Permit to Fly which had been issued by the Department of Transport on 11 May 1976, and which was valid until 11 August 1976. The aircraft was being maintained and certified in accordance with GAF Quality Assurance Instruction No. 1-3-6. Its total time in service at the time of the accident was 139 hours. The aircraft records indicate that prior to the commencement of the flight there were no maintenance deficiencies.

As the certification testing had not been completed for the N24 type, the maximum permissible take-off weight and the centre of gravity range had not been specified finally; the design limits were the same as those for which the N22 type had been certificated, i.e. a maximum take-off weight of 3855 kg (8500 lb) and centre of gravity limits of 21.5 to 38.5 per cent mean aerodynamic chord (MAC). The Permit to Fly for N24-10 specified a maximum take-off weight of 3855 kg.

The Configuration Requirement for the flight on which the accident occurred specified a start-up weight of 3855 kg and a centre of gravity position of 35.15 per cent MAC. The load sheet which was prepared for the flight, using nominal personnel weights of 91 kg per person, indicated that these specifications were met. The N24 aircraft had previously been flown at this and similar weights and centre of gravity positions with no difficulties having been experienced.

Subsequent to the accident it was established that at take-off the all-up weight was 3862 kg (8517 lb) and the centre of gravity position was 35.02 per cent MAC. This minor exceedence of the permissible all-up weight, which would not have affected the performance or handling of the aircraft, arose as a result of the use of nominal personnel weights instead of actual weights, and from a small difference in the actual weight of the ballast compared with that used for the original calculation.

The aircraft was fuelled with aviation turbine kerosene (AVTUR).

1.7 METEOROLOGICAL INFORMATION

The Avalon aerodrome forecast which was current at the time of the accident was originated by the Melbourne Regional Forecasting Centre at 0440 hours and covered the period from 0800 hours to 1800 hours.

Avalon aerodrome forecast:

Wind	:	220 degrees at 15 knots
Visibility	:	20 kilometres
Weather	:	Rain showers
Cloud	:	6/8 Cumulus, 2000 feet
Temperature	:	6, 9, 11, 12 degrees Celsius
QNH	:	1006, 1007, 1008, 1009 millibars

The Air Traffic Control Unit in Avalon Tower made weather observations at 0930 hours and 1200 hours which were passed to Melbourne Airport Weather Service Office.

Observation at 0930 hours:

Wind	:	260 degrees at 25 knots gusting to 35 knots
Visibility	:	In excess of 10 kilometres
Cloud	:	4/8 strato-cumulus, 3000 feet
Temperature	:	10 degrees Celsius
Dewpoint	:	5 degrees Celsius
QNH	:	1007 millibars

Observation at 1200 hours:

Wind	:	250 degrees at 20 knots gusting to 40 knots
Visibility	:	In excess of 10 kilometres
Weather	:	Rain
Cloud	:	5/8 strato-cumulus, 1500 feet
Temperature	:	11 degrees Celsius
Dewpoint	:	6 degrees Celsius
QNH	:	1007 millibars

The aerodrome terminal information service (ATIS) which the pilot of N24-10 advised having received prior to taxiing was designated 'DELTA'. It was first broadcast at 1036 hours and remained current until 1236 hours. It contained the following information:

> . . . wind two six zero, two five gusting three five, all crosswind, QNH one zero zero seven, temperature one zero, cloud five octas one five zero zero, showers in area . . .

The anemometer head for the recording of wind velocity at the aerodrome is located 12.5 metres above the ground, adjacent to the flight strip of the runway, almost directly beneath the flight path of N24-10. The evidence from this source indicates that the wind direction at the time of the flight was 270 degrees (True) at a mean speed of 23 knots varying between 16 and 31 knots.

The accident occurred in conditions of good visibility.

1.8 AIDS TO NAVIGATION

The availability and use of navigation aids was not relevant to the accident.

1.9 COMMUNICATIONS

Communications between civil aircraft and Avalon Tower are conducted on VHF radio frequencies and are recorded on continuously running magnetic tape. Communications were normal. A transcript of the communications between N24-10 and Avalon Tower is at Appendix C.

1.10 AERODROME INFORMATION

Avalon aerodrome contains one sealed runway which is aligned 360/180 degrees magnetic and is 3048 metres in length. Adjacent to the eastern boundary of the aerodrome the Government Aircraft Factories has prepared and maintains four grass strips. The use of these strips is restricted to GAF test pilots operating Nomad aircraft. The strip which was used for the take-off on the flight on which the accident occurred is aligned 270 degrees magnetic and is 640 metres in length and 30 metres in width. The western end of the strip is 890 metres east of the centreline of the runway. The aerodrome elevation is 23 feet.

1.11 FLIGHT RECORDERS

For the purpose of recording test data during development flights, the aircraft was equipped with an Ateliers de Construction de Bagneux (ACB) Type A1322 flight data recorder which uses light-sensitive paper as the recording medium. The recorder was mounted on the floor of the aircraft at approximately the mid-cabin position adjacent to the seat of the flight test engineer who controlled its operation by means of a hand-held switchbox which was connected to the recorder by a flexible cable. A condition specified in the Permit to Fly was that 'All test flying shall be conducted in accordance with GAF Project Note N2/44'. This Project Note specified that an ACB photographic trace recorder be fitted and that it be running continuously during all development flights. There was no requirement for a cockpit voice recorder to be fitted to this aircraft.

Data were recorded from the commencement of the take-off roll for a period of 28 seconds, following which the flight test engineer switched the recorder off to conserve recording paper until the aircraft had reached the flight test area. The following parameters were recorded:

Elapsed time	Tailplane control force
Indicated airspeed	Rudder angle
Altitude	Pitch attitude
Normal acceleration	Yaw attitude
Tailplane angle	Pitch angle
Tailplane tab angle	Roll angle

The readout of the record indicates that some 10 seconds after commencing its take-off roll the aircraft became airborne and almost immediately there were 'push–pull' control inputs for the next 5 seconds. During and subsequent to this period the aircraft was accelerating steadily and it then began to climb at a normal rate. When the record terminated the aircraft had reached an indicated airspeed of 106 knots and its altitude was 220 feet.

1.12 WRECKAGE AND IMPACT INFORMATION

The aircraft struck the ground at a point 1140 metres beyond the western end of the grass strip and 720 metres to the south of the extended centreline of that strip, having turned to the left through approximately 175 degrees after take-off. At the initial impact the aircraft was in a 20 degrees nose-down, 45 degrees left-wing-down attitude, and was yawed about 30 degrees to the left. The left wing tip struck the ground first, followed almost immediately by the impact of the left landing gear pod and the nose of the aircraft, after which the aircraft slid along the ground for about 70 metres and came to rest facing back along its approach path.

The cockpit area, the forward half of the cabin and the left stub wing had disintegrated as a result of the ground impact. Both wings were with the main wreckage, still attached to the remains of the mid-cabin structure. The engines remained attached to their respective wings but both propellers had separated. The left propeller came to rest to the rear and right of the aircraft; the right propeller, with portion of the reduction gear box, was in the main wreckage close to the left engine, having passed through the cabin during the ground slide. The rear fuselage structure was distorted in a manner consistent with the effects of the heavy ground impact.

A trail of small items of wreckage extended from the initial impact point to about 50 metres beyond the main wreckage, over a width of some 50 metres at the widest point. With the exception of five items of wreckage, all of the aircraft was contained within this general area. The five separate items were all from the left-hand tailplane and comprised three sections of lower skin from the second rib bay outboard of the root, part of the root rib at the trailing edge, and a 1.47 metre long inboard section of the T strip. They were found some 700 metres distant, close to the extended centreline of the grass strip which had been used for the take-off and about 1000 metres from its western end.

Both engines had been operating at impact and the initial marks made by the left-hand propeller indicated that the aircraft had a ground speed of 105 knots at that time. Using the mean wind as recorded by the aerodrome anemometer at the time of the accident, this ground speed corresponds to an indicated airspeed of 82 knots.

At the time of impact all doors and windows were closed and latched, and the landing gear and wing flaps were in the fully retracted position.

A detailed examination of the tailplane and its trim tabs disclosed that they had undergone violent oscillation in flight, in the course of which they had sustained severe structural damage. The most severe damage to the tailplane had occurred on the left-hand side, including a general failure of the structure aft of the main spar characterised by the collapse of the first five ribs due to repeated reversals of chordwise bending loads. The rib and skin failures had initiated immediately aft of the main spar, the degree of damage being more severe in the inboard areas.

There were several partial bending failures of the rear spar in the outboard half of the left-hand tailplane, and a partial downward bending failure of the main spar inboard of the leading edge mass balance location. A small section of the inboard end of the left-hand tab had broken away, but remained attached to the control rod; subsequent to this failure the inboard section of T strip had peeled off, starting from the inboard end. All of the major tailplane and tab structural failures showed evidence of repeated reversals of loading.

The right-hand tailplane and tab showed deformations and partial failures virtually identical with those of the left-hand side, although none had progressed to the same extent of damage.

Apart from the in-flight failures of the tailplane and tabs, all damage to the aircraft was consistent with the effects of ground impact. The wreckage examination disclosed no evidence of any other defect or malfunction.

1.13 MEDICAL AND PATHOLOGICAL INFORMATION

Post mortem examinations of the pilot and the observer indicated that both died as the result of injuries received during the impact of the aircraft with the ground. There was no evidence of pilot incapacitation or that his health was in any way impaired prior to or during the flight.

1.14 FIRE

No fire occurred in flight. The first person to reach the aircraft after it came to rest observed a small fire under the starboard wing, but it was blown out by the wind before he reached it. Paint blistering and staining on the inside of the starboard engine nacelle indicated that a low intensity, short duration fire had existed adjacent to the inboard exhaust duct.

1.15 SURVIVAL ASPECTS

The wreckage of the aircraft was located 560 metres from the Airport Fire Station and, as the crash alarm had been sounded prior to the aircraft striking the ground, the airport emergency vehicles were being manned before the aircraft came to rest. It is estimated that the rescue services were at the accident site one minute and twenty seconds after impact. The pilot was killed on impact and his body was located in the wreckage. He was strapped to his seat which had collapsed as a result of impact forces. The occupant of the right-hand pilot seat was ejected from the aircraft still attached to his seat; he died two days later as a result of the injuries he had sustained. The flight test engineer seated in the mid-cabin area suffered severe spinal injuries as a result of the collapse of his seat. The nature of his injuries was appreciated by the rescue personnel and he was not moved from the wreckage until personnel properly trained and equipped for handling this type of injury arrived at the scene.

The pilot and the flight test engineer wore protective helmets and sustained no significant head injuries although both helmets showed impact markings. The occupant of the right-hand pilot seat wore only a head-set and suffered fatal head injuries; however, the nature of his head injuries in toto was such that it is uncertain whether the wearing of a helmet would have improved his chances of survival.

1.16 TESTS AND RESEARCH

As both the wreckage examination and the witness reports indicated that some form of tailplane flutter had occurred in flight, a group was formed to investigate the flutter characteristics of the aircraft in the accident configuration. This group comprised appropriate specialists from the Department of Transport, the Aeronautical Research Laboratories and the Government Aircraft Factories.

Prior to the accident a flutter program had been developed by GAF and had been made use of during the design and certification of the N22 in order to study its flutter characteristics; this program was also being used for the same purposes in the case of the N24. As a first step in the investigation of the flutter phenomenon in the accident configuration, this program was modified by factoring the inertial and aerodynamic terms appropriate to the tabs by the ratio of the spans of the full-span and standard tabs, including an additional inertial contribution appropriate to the T strips but ignoring their effect on aerodynamics.

The results of the flutter calculations made with this modified program suggested that there could have been a critical flutter speed in the region of 120 to 130 knots for zero structural damping but, because of the approximations involved in the simplifying assumptions, this finding could not be considered as conclusive. Accordingly a research program was undertaken by the investigation group to establish better structural and aerodynamic representations of the modified tailplane installed on N24-10 at the time of the accident.

A comprehensive series of ground resonance tests was carried out on a new tailplane modified to incorporate the full-span tabs both with and without 50 mm T strips as fitted at the time of the accident. Difficulties were encountered during laboratory testing in accurately simulating the tab control circuit stiffness; therefore additional ground resonance tests were carried out with this modified tailplane fitted to a production N24 aircraft and the results obtained were used to correct the laboratory test results where necessary. These resonance tests showed that the tab frequencies for use in the flutter analysis would lie within the limits of 19–26 Hz.

It was considered that the available unsteady aerodynamic data were not suitable for the reliable prediction of the forces on a surface with trailing edge T strips. Therefore the investigation undertook a series of wind tunnel tests using a standard tailplane modified to make a two-dimensional wind tunnel model.

The tests were run at two tunnel speeds, 80 and 100 knots, and the tab was oscillated by shakers at frequencies of 5, 10, 20 and 30 Hz through an amplitude of ± 1 degree. The initial tests were carried out without T strips fitted, and showed good agreement with theoretical values over a frequency parameter range of 1.6 to 4.8. The tests were then repeated with 50 mm T strips fitted to the tabs. The results obtained enabled the preparation of a correction matrix to modify the theoretical pressure distributions so as to agree with the measured values. The aerodynamic coefficients used in the flutter calculations were derived from these values by applying a factor to account for viscous and three-dimensional effects. Based on previous experience the most likely value of this factor, referred to in the flutter program as FT, is 0.5 but the flutter calculations took account of the effect of variations in this parameter by allowing FT to vary between 0.5 and 1.0.

Tests carried out with 25 mm T strips fitted to the tabs instead of the 50 mm strips gave similar results, showing that the resulting aerodynamic effects were not sensitive to T strip width in the range 25–50 mm.

Measurements which had been made during earlier ground resonance tests on the standard N24 tailplane had shown that a structural damping level of between 2 and 4 per cent of the critical damping could be expected for the tailplane, and about 6 per cent for the standard tab. The full-span tab fitted at the time of the accident, with the greater friction generated by its longer piano hinge, would not be expected to have less structural damping than this. Nominal values of 2 per cent and 5 per cent respectively were used in the flutter calculations and these values were factored by a structural damping factor (SDF) which was varied between zero and 2.0 in order to study the effect of possible variations in structural damping.

The post-accident flutter analysis took account of a number of flutter models, and the results showed that flutter could occur in the case of a model comprising tailplane antisymmetric torsion at 33.8 Hz with antisymmetric rotation of the tabs at varying frequency. Critical flutter speeds were calculated for the full range of parameter variations referred to above and the results showed that flutter would occur at a speed within the range of 73 to 132 knots. The calculations indicated that the most likely value of the flutter speed, corresponding to SDF = 1.0, FT = 0.5, and the mid-range tab frequency of 22 Hz, was 103 knots EAS.

The mode of flutter revealed by the analysis was compatible with the damage observed on the tailplane and tabs. For the range of possible flutter speeds the frequency parameters were in the range of 4.0 to 6.4, these values all being well above the limiting figure of 2.5 specified by the Broadbent Criterion for cases of tab flutter (see Section 1.17.2).

A study of the damping ratios appropriate to various sets of parameter values over the range which could produce flutter showed that the onset of flutter would have been very rapid. At the most likely critical flutter speed of 103 knots EAS, a speed increment of 2 knots produces a growth rate of 1 per cent: this corresponds to a doubling of amplitude in each successive 11 cycles and, as the flutter frequency in this case is 29 Hz, the time to double amplitude would be about 0.4 seconds. Thus the time from the onset of flutter to its reaching catastrophic proportions would be very short—of the order of a few seconds.

Flutter speeds were calculated for other tab configurations incorporating the various tab spans with and without 25 mm and 50 mm T strips. Some of these configurations had been flown during the flight test program and the calculations thus provided a partial check on the validity of the mathematical model used, and also an indication of the flutter margins which had existed during the various stages of tab modification. In Appendix D, which summarises these results, the flutter speeds quoted are those corresponding to the most likely parameter values, i.e. SDF = 1.0 and FT = 0.5, with the appropriate mid-range tab frequency in each case.

1.17 ADDITIONAL INFORMATION

1.17.1 Tailplane and tab modifications

The N22 and N24 aircraft are fitted with an all-moving tailplane pivoted at 22.9 per cent of its chord. Aerodynamic 'feel' is provided by two geared trailing edge anti-balance tabs, each of which has a semi-span of 1.75 metres. The tabs are also controllable from the cockpit to provide longitudinal trim.

During the development flight testing of the N24 it had been judged that the stick force gradient when operating with 20 degrees of flap was not acceptable for certification purposes. Positive gradients had been measured but they were very small at low speeds and were not sufficient, in the opinion of the Company's Senior Test Pilot, to meet the certification requirement that 'the stick force must vary with speed so that any substantial speed change results in a stick force clearly perceptible to the pilot'.

A number of modifications were made by the manufacturer in attempts to improve the stick force gradient in the 20 degree flap configuration. These included various combinations of tailplane fences, vortex generators, leading edge extensions, a change in the tailplane pivot location, and a series of changes in the configuration of the tabs. As these modifications had not achieved the desired result, the manufacturer decided to submit the N24 for certification without a 20 degree flap position, and to examine the situation further during the development of the proposed N24A model of the aircraft.

The modifications of principal concern to this investigation are those which involved the sequence of changes to the tab configuration, and these are listed below in the order in which they were flown. The 25 mm and 50 mm T strips referred to are illustrated in Appendix E. Apart from these additions and the changes in span of the tabs, the tailplane structure and installation was not altered.

Flight 93, 20 May 1976

This flight used standard length tabs (of 1.75 m semi-span) with 25 mm T strips fitted to the tab trailing edges.

Flight 94, 21 May 1976

The same tab configuration, but with 25 mm T strips also fitted to the tailplane trailing edges outboard of each tab.

Flight 96, 25 May 1976

The T strips were removed from the tabs, but were retained on the tailplane trailing edges.

Flight 97, 26 May 1976

The tailplane trailing edges were fitted with 50 mm T strips, still with none on the tabs.

Flight 100, 3 June 1976

The tab length was increased by 0.41 m to a semi-span of 2.16 m. There were no T strips on the tabs or the tailplane.

Flight 101, 4 June 1976

The tab length was increased by a further 0.41 m to encompass the full span of the tailplane. No T strips were fitted.

Flight 128, 6 August 1976 (accident flight)

The full-span tabs were fitted with 50 mm T strips.

1.17.2 The Broadbent Criterion

In the case of a new aircraft design, the development program is usually such that the initial flight tests are scheduled before the flutter computations, which of necessity are lengthy, have been completed; therefore, a preliminary flutter clearance, usually to a restricted airspeed, is required to enable flight testing to proceed. To determine freedom from flutter without carrying out a detailed flutter analysis, there are several simplified design criteria which may be used. One of these is the Broadbent Criterion ('The elementary theory of aero-elasticity', E. G. Broadbent, *Aircraft Engineering*, March–June 1954). This criterion includes a safety factor; therefore a speed derived from its application is not a flutter speed, but is a speed at which past experience has shown that a conventional aircraft can be operated without risk of flutter.

The Broadbent Criterion specifies that:

(1) main surface flutter does not occur at frequency parameters greater than unity

(2) control surface flutter (no tabs) does not occur at frequency parameters greater than 1.5

(3) tab flutter does not occur at frequency parameters greater than 2.5

The frequency parameter is given by:

$$v = \frac{\omega c}{V}$$

where ω = flutter frequency, radians/second
c = chord of the main surface, feet
V = equivalent air speed, feet/second

2 ANALYSIS

The investigation has revealed that after a normal take-off, as the aircraft was climbing on its departure for the flight test area, tailplane flutter occurred at a height of about 950 feet. The post-accident flutter calculations have shown that the critical flutter speed would have been in the vicinity of 103 knots, and the flight recorder evidence is that the aircraft had achieved a speed of 106 knots some 30 seconds before the flutter occurred. There is no evidence of the precise speed at which flutter occurred, but the normal climbing speed is in the vicinity of 110 knots and there is evidence from the flight test engineer that the climb was normal.

It has been calculated that, at the most likely value of the critical flutter speed, the amplitude of the oscillations would double in each successive 0.4 seconds and thus the onset of flutter would have been sudden and very severe. Such a rapid build-up could be expected to produce substantial damage within a few seconds, and the nature of the damage to the tailplane and tabs was consistent with the mode of flutter revealed by the calculations. The close grouping of the five pieces of tailplane wreckage which were recovered on the ground below the flight path confirms that the partial destruction took place during a short time interval; their location on the ground was consistent with the position at which witnesses had observed the tailplane fluttering as the aircraft was climbing after take-off and also the position at which the flight test engineer stated that vibration commenced.

The extent of the damage to the tailplane and trim tabs indicates that subsequent controllability of the aircraft in the pitching plane would have been seriously degraded. The aileron and rudder controls were intact and it is possible that the turn back towards the aerodrome was initiated by the pilot, but there is no certainty of this. Whether or not the turn was intentional, it is considered that an uncontrolled or at best a partially controlled ground impact became inevitable at the time that the tailplane and trim tabs suffered severe structural damage, thus virtually depriving the pilot of longitudinal control of the aircraft; consequently the causal factors for the accident must be sought in the circumstances which led to the occurrence of this damage.

The aircraft was properly crewed and there was no evidence that incapacitation, loading or weather contributed to the accident. The examination of the wreckage disclosed no evidence of any defect or malfunction with the exception of the in-flight failures of the tailplane and trim tabs. All other damage was consistent with the effects of impact with the ground.

The tailplane and trim tabs fitted to the N24 type were the same as those fitted to the N22 type, which had been demonstrated by calculations and flight testing to be free from flutter throughout its flight envelope. The tailplane modifications which were carried out on N24-10 with a view to improving the stick force gradient at the 20 degree flap setting proposed for use on the N24A were progressive in nature. First, 25 mm T strips were attached to the trim tabs and then to the entire trailing edge without significant effect on the stick force gradient. Tests were then carried out with 25 mm and, later, 50 mm T strips attached to the tailplane trailing edge, but not the trim tabs, again without significant effect. A different approach was then made, in which the T strips were discarded and the size of the trim tabs was increased in two steps until they extended over the entire trailing edge of the tailplane; once again there was no discernible effect on the stick force gradient with 20 degrees of flap extended. It was then that the decision was made to install full-span trim tabs with full-span 50 mm T strips attached to their trailing edges.

The sequence of modifications of the tailplane and trim tabs had been initiated by the acting Chief Designer, and an airspeed limitation of 120 knots had been imposed for all test flights. The responsibility for ensuring structural integrity, including freedom from flutter, rested with the position of Senior Designer Structures and Mechanical. Freedom from flutter at 120 knots was checked by the use of the Broadbent Criterion (see Section 1.17.2) with the known N24 tailplane and tab frequencies adjusted to account for the effect of the various modifications. There is direct evidence that this procedure was applied to all modifications preceding the final one.

The investigation has established that the static structural strength of the final tab and T strip configuration was not a factor in the accident, the T strip having remained intact until destructive loads had been generated by flutter. As far as flutter clearance for the final flight is concerned there is some evidence to suggest that the acting Chief Designer, who at the time of this particular flight was also carrying out the duties of Senior Designer Structures and Mechanical, had used the Broadbent Criterion in order to verify that 120 knots remained a safe airspeed limitation but no record has been found of any flutter calculations which he may have made. Calculations made subsequently have shown that the information then available would have resulted in a calculated tab frequency of 20.0 Hz (compared with 19.2 Hz measured as the lowest tab frequency during the post-accident tests). On the basis of the limiting frequency parameter of 2.5 for tab flutter, the safe flight test speed calculated in accordance with the Broadbent Criterion is 129 knots EAS. For the case of tailplane flutter, using the known tailplane rotation frequency of 11.1 Hz and the appropriate frequency parameter of 1.5, the safe speed would have been calculated as 119 knots EAS.

The Broadbent Criterion is an empirical rule the application of which is limited to aircraft which do not represent a radical departure from conventional practice. A speed determined from the application of this criterion would normally be expected to embody a substantial safety factor which would ensure that there was no possibility of flutter provided the speed was not exceeded. The investigation has shown, however, that destructive flutter occurred at a speed less than the 120 knots EAS established by the Broadbent Criterion as a safe speed; and the most likely value of the critical flutter speed revealed by the post-accident flutter analysis is 103 knots EAS in the accident configuration. Similarly, the most probable flutter speed for the standard tabs fitted with 25 mm T strips is 125 knots EAS (see Appendix D). It is evident, therefore, that the addition of even the smaller T strips to the N24 standard tailplane tabs produced a design for which the application of the Broadbent Criterion did not provide an adequate safety margin.

The decision to use the Broadbent Criterion to check that the aircraft would be free from flutter at the maximum flight test speed of 120 knots to be used during the tailplane modification program was taken by the GAF design personnel with the benefit of extensive experience and knowledge of the flutter characteristics of the N22 and N24 aircraft. The alternatives which were available to them at each step of the program were to apply one of the simplified design criteria or to carry out complete flutter analysis. No theory was available which could reliably predict the additional aerodynamic forces generated by the trailing edge T strips, and thus any flutter analysis made for the various configurations of the development program would have had to be based on conventional aerodynamic theories, using parameter variations to assess the effects of increased aerodynamic forces.

The principle of using trailing edge T strips to modify the control force characteristics was not a radical departure from accepted practice. Furthermore, with the knowledge then available the designers' decision to apply the Broadbent Criterion was not unreasonable. It was only as a result of the extensive and detailed flutter test program, which was undertaken as part of the accident investigation, that it was determined that the use of T strips, in this case, resulted in aerodynamic forces substantially in excess of those which could reasonably have been expected. The magnitude of the aerodynamic changes thus invalidated the Broadbent Criterion as a determinant of freedom from flutter.

The mode of flutter which gave rise to this accident was a combination of tailplane antisymmetric torsion and tab rotation which occurred at a relatively high frequency and with a frequency parameter in excess of that indicated by previous experience. The addition of T strips to the trailing edges of the tailplane trim tabs resulted in aerodynamic and inertia effects which led to an essentially flutter-free structure becoming flutter critical.

3 CONCLUSIONS

1. After a normal take-off, at a height of about 950 feet and at an airspeed of about 110 knots, flutter of the tailplane and trim tabs occurred; they sustained structural damage to the extent that the pilot was deprived of effective control of the aircraft in the pitching plane.

2. The aircraft entered a descending turn to the left; at a low height, all control was lost and it struck the ground.

3. The purpose of the flight was to carry out tests to determine the stick force gradient after full-span trim tabs with trailing edge T strips had been fitted to the tailplane. This was the first flight with this modification.

4. The pilot was appropriately qualified and licensed.

5. Weather conditions were not a factor in the accident.

6. The aircraft was loaded within safe limits.

7. The aircraft was appropriately maintained and certified. With the exception of in-flight failures of the tailplane and trim tabs, there was no evidence of any defect or malfunction which could have contributed to the accident.

8. The flutter occurred as a result of the aerodynamic and inertia effects of the T strips which were attached to the trailing edges of the trim tabs.

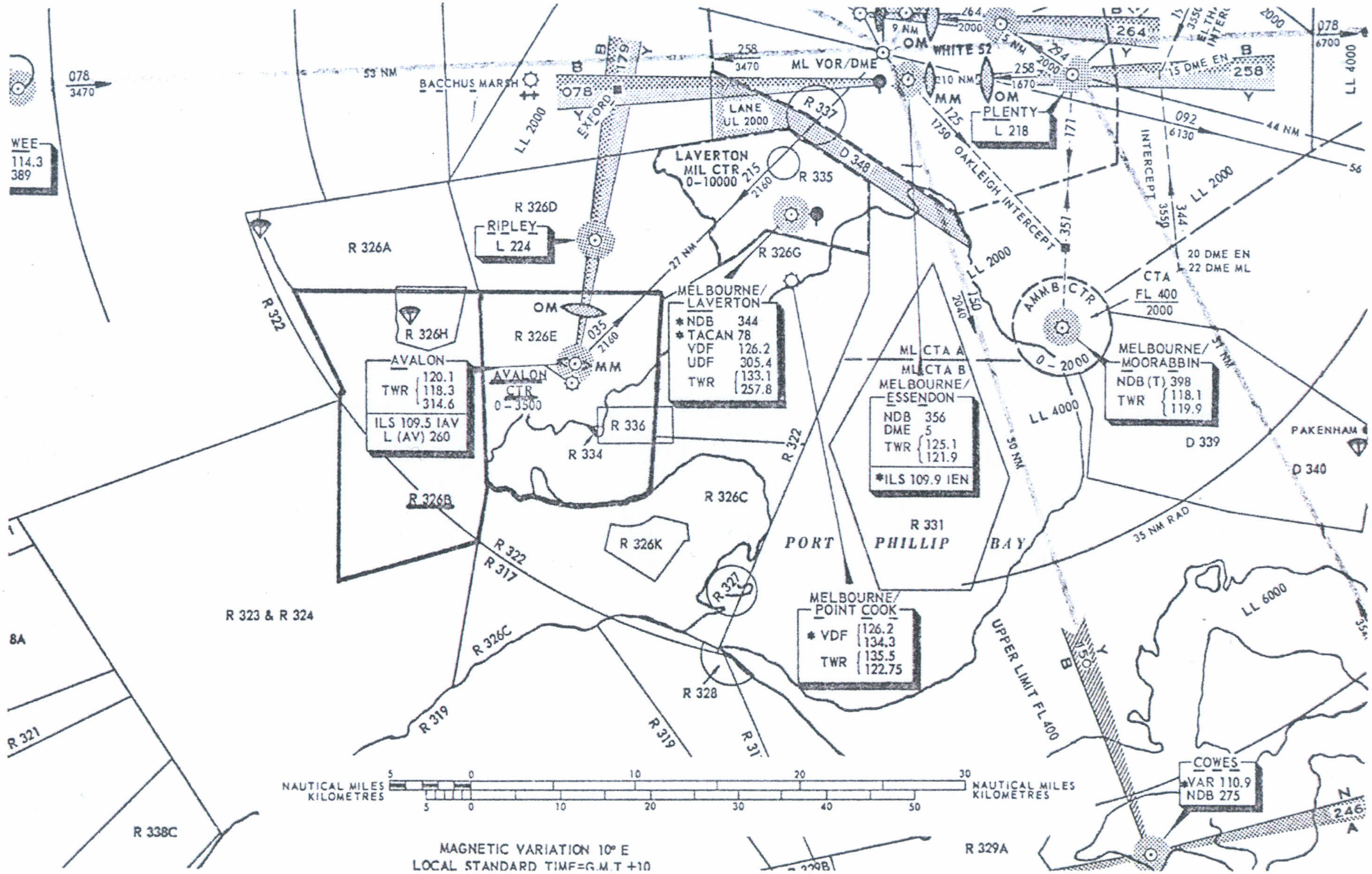
9. The modification of the tailplane and trim tabs was authorised by the manufacturer's design staff who were appropriately qualified.

10. A simplified design criterion was used to determine that, up to a maximum flight test speed of 120 knots, the modified tailplane and trim tabs would be free from flutter.

11. Post-accident research has shown that the tailplane modification resulted in a design to which the simplified design criterion did not apply.

CAUSE

The cause of the accident was that the simplified design criterion which was used to justify freedom from flutter during the flight testing of various tailplane modifications was not valid for a design which included tab trailing edge T strips.



WEE
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R 335
D 348
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351
INTERCEPT
355
344
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R 326D
RIPLEY
L 224
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R 326G
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ESSENDON
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MOORABBIN
NDB (T) 398
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119.9
LL 4000
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118.3
314.6
ILS 109.5 IAV
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CTR
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R 334
R 322
50 NM
D 339
PAKENHAM
D 340
R 326B
R 326C
R 326K
PORT PHILLIP BAY
R 331
35 NM RAD
R 322
R 317
R 327
R 323 & R 324
8A
R 326C
MELBOURNE/
POINT COOK
VDF 126.2
134.3
TWR 135.5
122.75
UPPER LIMIT FL 400
150
LL 6000
R 321
R 319
R 328
R 319
NAUTICAL MILES
KILOMETRES
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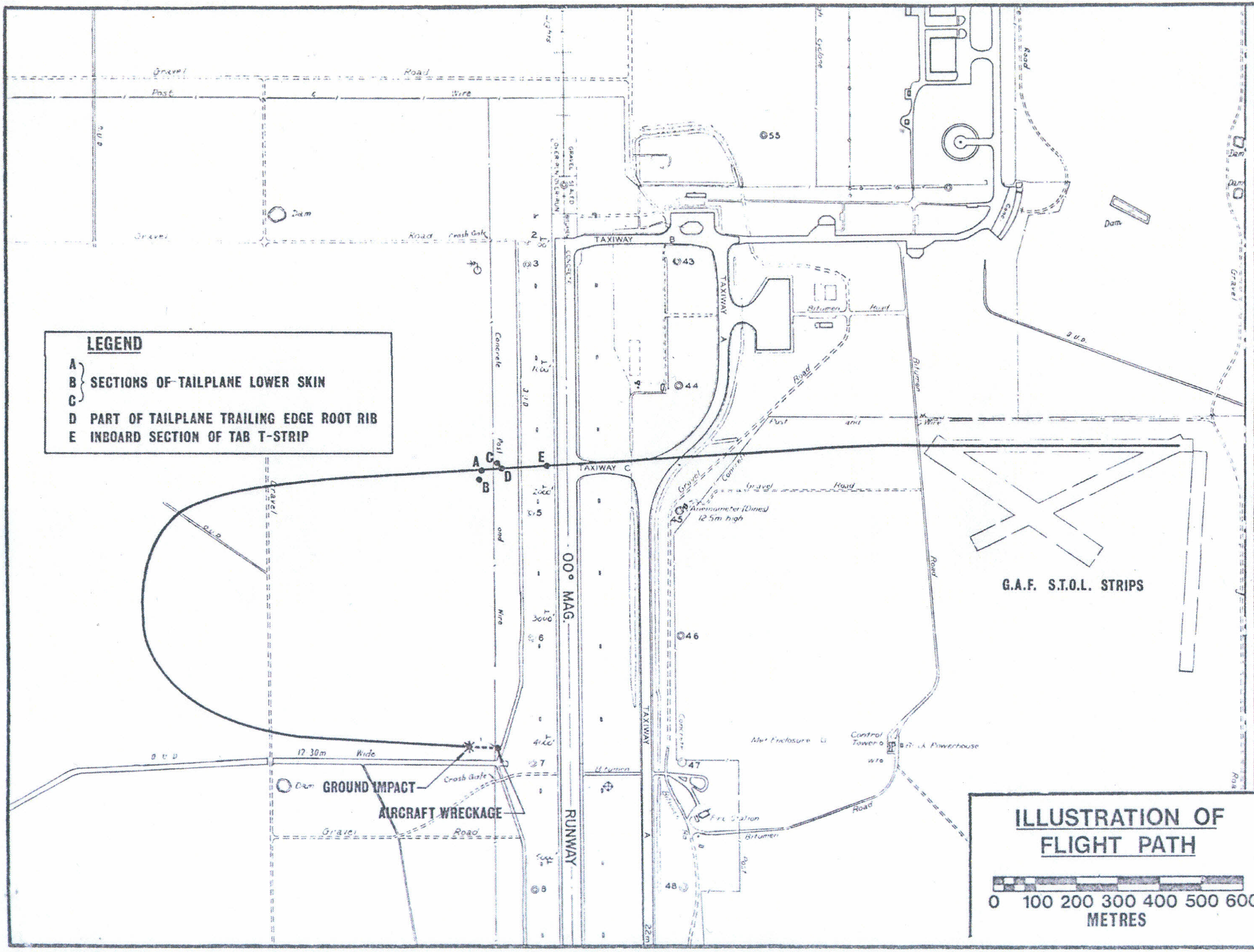
5 0 10 20 30 40 50
COWES
VAR 110.9
NDB 275
246
R 338C
MAGNETIC VARIATION 10° E
LOCAL STANDARD TIME=G.M.T +10
R 329A
R 329B


LEGEND
A
B SECTIONS OF TAILPLANE LOWER SKIN
C
D PART OF TAILPLANE TRAILING EDGE ROOT RIB
E INBOARD SECTION OF TAB T-STRIP
TAXIWAY B
TAXIWAY A
TAXIWAY C
00° MAG.
RUNWAY
GROUND IMPACT
AIRCRAFT WRECKAGE
G.A.F. S.T.O.L. STRIPS
Anemometer (Dines) 12.5m high
Control Tower
Fire Station
Met Enclosure
ILLUSTRATION OF FLIGHT PATH
0 100 200 300 400 500 600
METRES

APPENDIX C

TRANSCRIPT OF COMMUNICATIONS CONCERNING NOMAD AIRCRAFT N24-10 RECORDED AT AVALON TOWER BETWEEN 1051 HOURS AND 1103 HOURS ON 6 AUGUST 1976

Legend

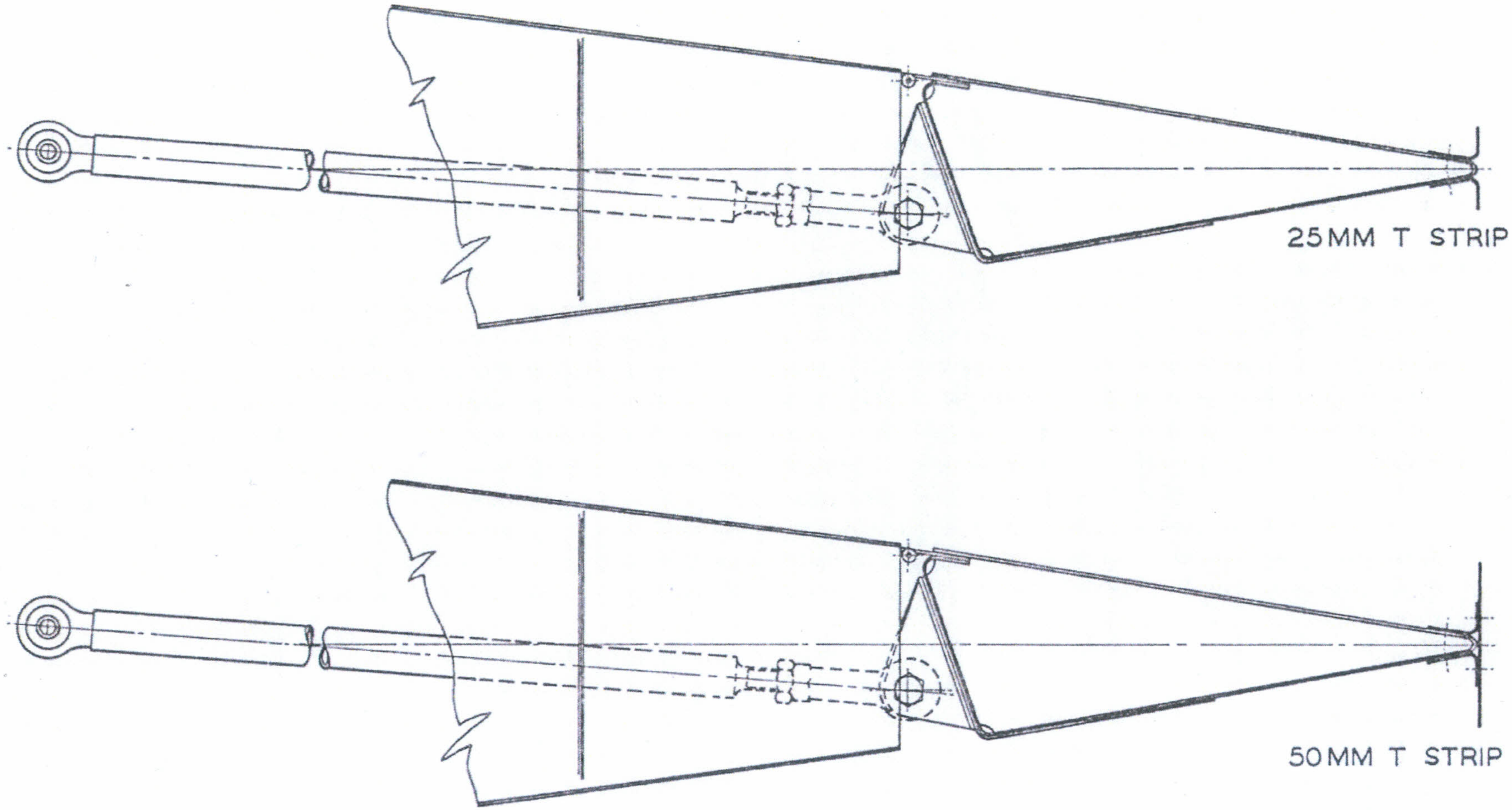
GAF 1	Nomad aircraft N24-10 callsign GAF ONE
GAF 2	Nomad aircraft N2-01 callsign GAF TWO
TWR	Avalon Tower (Aerodrome/approach controller)
SEC	Sector 1 Melbourne AACC
CAR 62	Radio-equipped airport vehicle callsign CAR SIX TWO
AFS	Avalon Fire and Rescue Service Unit
(?)	Unidentified source
—	Unintelligible word(s)
/ / / /	Editorial insertion

Time h/min/s	*From*	*To*	*Text*
1051:00			
1051:08	GAF 1	TWR	GAF ONE ah AVALON received ah DELTA taxi
:15	TWR	GAF 1	GAF ONE AVALON TOWER confirms for the stol strip
	GAF 1	TWR	Affirmative
:20	TWR	GAF 1	GAF ONE roger taxi the time is five one a half
	GAF 1	TWR	Roger GAF ONE
1052:00			
:23	TWR	GAF 2	GAF TWO your big brother's on the way up to the stol strip
:28	GAF 2	TWR	– – TWO ah roger
:35	GAF 1	GAF 2	Ah TWO I'll hold down here in the stol strip area
:51	GAF 1	GAF 2	Ah TWO from ONE you can come on up the road if you like umm I just wanna have a chat with this fellow with this aeroplane on the compass base here
	GAF 2	GAF 1	Roger
1053:00			
:41	GAF 1	GAF 2	Mind the wing Pete
:46	GAF 2	GAF 1	Too much camber on this road
:48	GAF 1	GAF 2	The wind's a bit strong too I think
	(?)	(?)	– –
1054:00			
1055:00			
:53	GAF 1	GAF 2	Ah TWO from ONE can you go to one two zero zero for a minute

1056:00			
1057:00			
1058:00			
:45	TWR	GAF 1	GAF ONE just for information there's light cloud coming through now it's er one five zero zero feet with lower patches and aircraft report extensive ah cloud and build-ups extending right down to Torquay and drifting through on a north-easterly heading
1059:00			
:01	GAF 1	TWR	Roger GAF ONE thanks very much er I'll take a quick look at it and er see if ah we can er operate in that area in the in the northern half of BRAVO
:12	TWR	GAF 1	GAF ONE ah roger it looks as though its okay at the moment but I don't think it'll last
:15	GAF 1	TWR	No roger we'll keep an eye on it thanks
:53	GAF 1	TWR	GAF ONE request clearance
:57	TWR	GAF 1	GAF ONE your clearance operate ROMEO three two six BRAVO not above one zero thousand
1100:00			
:01	GAF 1	TWR	GAF ONE BRAVO up to ten ready
:04	TWR	GAF 1	GAF ONE short delay
:23	TWR	GAF 1	GAF ONE climb unrestricted clear for take-off
:26	GAF 1	TWR	GAF ONE thank you
1101:00			
:25	TWR	SEC	GAF ONE is airborne to the north end of runway one eight and er heading west
:42	TWR	GAF 1	GAF ONE just confirm confirming that you can
:48			/ /4.5 second pause/ / GAF ONE ops normal?
:50	GAF 1	TWR	Negative negative
1102:00			
:02	TWR	GAF 1	GAF ONE crosswind on runway gusting three five clear to land
:05	TWR	CAR 62	CAR SIX TWO vacate immediately
:09	AFS	TWR	Hello
	TWR	AFS	Get the fireys there he's had a — —
	AFS	TWR	Yeah I know about it
	(?)	(?)	Okay
	(?)	(?)	— —
	(?)	(?)	Okay
:28	TWR		Standby police standby hospital standby fire brigade

Summary of calculated flutter speeds and the speeds achieved in flight tests

Tab configuration	*Most probable flutter speed—knots*	*Speed to which aircraft was flown—knots*
Standard (1.75 m)		
—no T strips	no flutter	218
—25 mm T strips	125	120
—50 mm T strips	115	not flown
Extended (2.16 m)		
—no T strips	no flutter	120
Full span (2.57 m)		
—no T strips	no flutter	118
—25 mm T strips	106	not flown
—50 mm T strips	103	approx. 110



TAB TRAILING EDGE T STRIPS