No. 2

Spantax, Convair CV 990, EC-BNM accident at Stockholm/Arlanda Airport, Sweden, on 5 January 1970. Report, dated 23 December 1970, released by the Board of Civil Aviation, Sweden

1.- Investigation

1.1 History of the flight

The aircraft was originally planned to fly a non-scheduled international flight from Stockholm/Arlanda to Palma de Mallorca. During the take-off run No. 4 engine did not function properly; the take-off was aborted and the aircraft was taxiied back to the apron. Inspection of the engine revealed damage to the compressor. After consultation with the Spantax Operations Department in Madrid, it was decided to ferry the aircraft on three engines to Zurich, where No. 4 engine would be changed.

The technical preparation of the aircraft for the ferry flight was supervised by a ground engineer from Spantax. Meanwhile, the flight crew planned the flight. As the ATS briefing office at Arlanda was closed after 2100 hours, the co-pilot phoned the ATS flight plan to Stockholm Control Centre (ACC). Neither when phoning the flight plan nor at the weather briefing did the crew advise that the flight was a 3-engine ferry flight. However, the Air Traffic Controller (Tower) in some other way had been informed about the nature of the flight.

At 2208 hours the crew received a taxi clearance to Runway 08, but as they considered that this runway was too short for a 3-engine take-off, they requested permission to use Runway 19 and this was granted. Another advantage of using Runway 19 was that it made it possible to join the outbound track with minor heading changes. During taxiing the aircraft and the engine anti-icing system were checked according to the check list. (After checking the engine anti-icing was switched OFF.) At 2221 hours the flight was cleared to take-off, and at 2224 hours the crew reported "Rolling".

According to the pilot-in-command, maximum EPR take-off power was set on engines Nos. 1, 2 and 3 with brakes on, then, after having checked the instruments, No. 1 engine was throttled back to 85 per cent and the brakes were released. When the aircraft had rolled for 5-10 seconds the nose wheel skidded to the right and to regain heading he had to retard throttle No. 1 to 80-60 per cent. When back on the centre line he slowly opened the throttle again. Maximum EPR take-off power was set when the aircraft reached a speed of 100 kt. He rotated the aircraft at the calculated speed Vr - 134 kt (27^{o} of flaps) and it became airborne. He retracted the gear when positive climb was indicated. Just after lift off he was blinded by the aircraft landing lights illuminating unexpectedly low clouds over the runway. Initially he kept the speed at V_2 (145 kt) and noticed a rate-of-climb of 800 ft/min. He had to apply extremely hard left rudder to centre the turn indicator (ball). He did not observe any bank or turn tendency, but noted that the indicated airspeed (IAS) was not increasing normally and shortly thereafter that the rate-of-climb and speed decreased. The pilot-in-command felt they urgently needed more power, but all happened very quickly and shortly after he had noticed the speed drop the aircraft collided with the terrain. From the time take-off power had been set on the runway the throttle positions were not changed.

The co-pilot stated that they had to taxi down the runway to avoid ice patches on the first part of the runway. He could not say how far they taxiied and it was not possible to determine it in any other way. During preparation for take-off he asked the pilot-in-command if they should use 10° flaps, but the decision of the pilot-in-command to use 27° was not changed. He completed the pre-take-off instrument check and did not notice any abnormal readings. The three gyro horizons indicated no differences. When rolling he kept the control column forward, to increase the friction on the nose wheel, and gave full left aileron. Gradually he decreased the pressure on the column and reduced left aileron deflection. At V_1 the pilot-in-command took over the controls. The co-pilot kept his left hand on the throttles and verified that no changes were made on throttles Nos. 2 and 3 after take-off power was set, but he noticed that the pilot-in-command had to vary the No. 1 throttle setting several times during the roll. After lift-off when the gear was retracted the co-pilot received a message from the tower giving the take-off time and instruction to change over to STOCKHOLM RADAR on 124.1 MHz. He never acknowledged the message but when leaning forward to select the new frequency he noticed on his horizon a banking to the right of 4 to 6°. He also observed the gyro horizon of the pilot-in-command indicating a bank to the right. The speed had dropped to 10 kt below V_2 and he called: "The speed, the speed". He felt no buffeting in the aircraft and noted no tendency to Dutch roll. He also stated that he observed a power drop of about 2 per cent below EPR take-off power. Shortly after the first contact with the tree-tops the banking to the right had increased to 10-15° and the co-pilot retarded the throttles.

The flight and the ground engineers sitting in the cockpit observed nothing abnormal until the crash. None of them observed any indications of power changes on the instruments. No buffeting was felt in the aircraft, neither were any warning signals heard.

Whilst in a right bank of 4-6° the aircraft collided with tree-tops approximately 26 m above and 1 060 m from the far end of Runway 19, or about 1 800 m from the point of lift-off, having turned through about 25 degrees from the runway heading. The aircraft came to a final stop approximately 500 m after first contact with the trees on a heading of 240° (see Fig. 2-1). The accident occurred at 2225 hours at night in complete darkness.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	5*		
Non-fatal	3 + 1*		
None	1*		

*Crew members not in the cockpit, except one ground engineer.

1.3 Damage to aircraft

Destroyed.

1.4 Other damage

Various damage to the forest was caused by the accident. The aircraft contained approximately 30 400 kg (67 000 lb) of fuel at the time of the accident. To reduce the risk of contamination of the ground water, officials from the community were allowed to dig holes at the impact site in an attempt to locate the fuel. Only small quantities were found. The ground water used after the accident was not contaminated.

1.5 Crew information

The pilot-in-command, aged 41, held an airline transport pilot's licence valid until 16 February 1970. He had passed his last medical check on 16 July 1969 and his last proficiency check on 6 October 1969. He had flown a total of 10 019 hours, including 2 318 hours in CV 990 aircraft and had carried out a number of 3-engine ferry flights on that type of aircraft, the most recent having been on 13 May 1969. He had completed 44 hours duty time during the last 30 days, 34 hours during the last 7 days and 8 hours during the 24 hours prior to the day of the accident. On the day of the accident he had completed 12½ hours duty time.

The co-pilot, aged 29, held an airline transport pilot's licence valid until 6 March 1970. He had passed his last medical check on 16 October 1969 and his last proficiency check on 30 July 1969. He had flown a total of 5 861 hours, including 758 hours in the CV 990 aircraft. He had completed 33 hours duty time during the last 30 days, 21 hours during the last 7 days and 0 hour during the 24 hours prior to the day of the accident. On the day of the accident he had completed 12½ hours duty time.

The flight engineer, aged 43, held a flight engineer's licence valid until 22 June 1970. He had passed his last medical check on 11 June 1969 and his last proficiency check on 28 July 1969. He had flown a total of 3 319 hours, including 970 hours in the CV 900 aircraft. He had completed 42 hours duty time during the last 30 days, 21 hours during the last 7 days and 0 hour during the 24 hours prior to the day of the accident. On the day of the accident he had completed 12½ hours duty time.

Also aboard the aircraft were one ground engineer who was seated behind the pilot-in-command, and six cabin attendants, all properly certificated.

Although all flight crew members had been on duty for 12½ hours on the day of the accident, due to the unforeseen delay, the Commission did not find any indication that crew fatigue contributed to the accident.

1.6 Aircraft information

The Certificate of Airworthiness of the aircraft was valid. The aircraft had flown a total of 16 940 hours, of which 3 914 hours had been flown since the last major overhaul which had been performed by American Airlines, the previous owner, in January 1968.

The powerplants were four General-Electric CJ-805-23 turbofan engines. They were installed as follows:

Position	Engine S/N	Total time	Time since overhaul
1	175 - 146	11 687	2 656
2	175 - 173	9 307	1 284
3	175 - 232	8 930	1 740
4	175 - 161	10 860	1 639

According to the Aircraft Logs, retained by the maintenance contractor (Swissair) S and T checks had been performed on 25 October 1969 and at that date the aircraft had a total time of 16 755 hours. The next S and T checks were to be performed before a total of 16 975 hours and 17 355 hours respectively.

According to the Spantex Aircraft-Log, which was found in the cockpit, L-check was performed at Arlanda on 5 January 1970. Nos. 1 and 4 engines were each topped-up with one quarter of a gallon of oil (Castrol 30) - no oil was added to engine Nos. 2 and 3.

For the flight to Palma de Mallorca the aircraft had been refuelled with 25 000 litres of JP-1 fuel, giving a total fuel load of 30 800 kg (68 000 lb). Following the aborted take-off the aircraft was not defuelled before the flight to Zurich and according to the loadsheet for the flight the total fuel load was 30 400 kg (67 000 lb) with the same estimated fuel consumption as that for the original flight, i.e. 22 800 kg (50 000 lb).

The calculated take-off weight of the aircraft was 87 347 kg (192 563 lb). The maximum allowable take-off weight for 3-engine take-off with 10° flaps and the prevailing conditions was 98 500 kg (217 500 lb). The Aeroplane Flight Manual did not include calculation for a take-off with a 27° flap setting for the prevailing conditions; however, the aircraft type has sufficient performance. The centre of gravity limits for the flight were 16.2 per cent mean aerodynamic chord (MAC) forward and 32 per cent MAC aft. The aircraft's centre of gravity was at 25.5 per cent MAC.

1.7 Meteorological information

The local Spantax representative and the co-pilot received a weather briefing and appropriate documentation for the flight to Zurich, probably between 2030 and 2100 hours. At about 2130 hours the co-pilot returned to the meteorological office and received the latest weather information re Zurich and Geneva. He had available on a television screen (ITV) the actual weather at Arlanda; the display between 2120 and 2150 hours was: wind 320°/2 kt, visibility 5 km, clouds 3/8 at 100 ft and 6/8 at 200 ft, temperature -26°C.

At 2220 hours the following weather was reported by the observer at Arlanda: wind calm, visibility 2.5 km, 3/8 Stratus at 100 ft, 5/8 Stratus at 200 ft, temperature -27°C, QNH 997.0 mb, relative humidity 79 per cent.

According to an aircraft which landed at 2216 hours it was possible to see the approach and runway lights all the way through the clouds. The base of these clouds was estimated to be between 30 and 50 ft above the ground.

According to the crew of another aircraft a thin layer of rime ice formed on the windshield when passing through the stratus cloud layer.

The vertical temperature distribution is not measured at Arlanda but upper-air observations were carried out at Bromma (approximately 35 km south of Arlanda) about one hour after the accident. The radiosonde at Bromma gave the following temperatures and dewpoint temperatures:

Height above surface	Temperature (°C)	Dewpoint (°C)
0 m	-21.0	-23.5
174 m (570 ft)	-11.4	-13.0
330 m (1 080 ft)	- 7.0	-13.9

On the same ascent the following upper winds were observed:

0 m	320/4 kt
1 238 m (4 100 ft)	040/10 kt

It was determined that the ground inversion at Arlanda involved a temperature rise of approximately 10°C from the ground surface to a height of 170 ft above the ground. Furthermore it was determined that for a period of about two hours before the accident the layer of low stratus over the aerodrome had been moving from the NNW at a speed of 5-10 kt although the wind was calm at the surface. Additionally, examination of some flight recorders from other aircraft which had taken off and landed at Arlanda confirmed the presence of wind shear. The examination, however, did not reveal the exact magnitude of the wind shear, but indicated that the speed was probably closer to 5 kt than to 10 kt.

1.8 Aids to navigation

Not applicable.

1.9 Communications

No communications difficulties between the aircraft and the tower were experienced.

1.10 Aerodrome and ground facilities

Arlanda airport had two runways: RWY 08/26 which was 2 500 m long and RWY 01/19 which was 3 300 m long. Both runways had a width of 45 m. The surrounding area was sparsely populated and mostly covered by forests.

The aircraft took off on Runway 19, the runway lighting was operating at the time of take-off as well as the approach lighting for Runway 01.

An inspection of the runway earlier on 5 January 1970 had revealed the presence of some ice patches on an otherwise dry surface and braking action on the runway was reported "Good" and equal to a friction coefficient of 0.40 or more. There was no reason to assume that there had been any change in these conditions between the time of the inspection and the time of take-off.

Due to the low stratus the tower controller could only see a part of the middle of the runway. The primary and secondary surveillance radar as well as the VDF were functioning properly at the time of take-off; however, no indication of the aircraft take-off was obtained on the radar or Distance From Touchdown Indicator (DFTI).

1.11 Flight recorders

The aircraft was equipped with a Lockheed Aircraft Service type 109C flight data recorder which was installed in the left main wheel well. After the crash it was found damaged on the ground under the left wing. The foil magazine was loose and the scriber arms had partly destroyed the foil. It was sent for readout to the U.S. National Transportation Safety Board.

At the preliminary check it was noted that all parameters had been operating but that the movement of the foil had not functioned properly. The malfunctioning of the recorder had existed for a long time before the crash. The movement of the foil had been intermittent and periodically was too fast. For that reason the values of the parameters could not be correlated with time. It could only be determined that during the take-off roll the aircraft yawed 8-10° to the right, turned back to 180° and then gradually regained the correct heading: after lift-off the aircraft turned right to a final heading of 240°. The altitude trace was difficult to interpret, but possibly indicated a maximum altitude of 250 ft. The other registrations were unreliable.

No mention of cockpit voice recorder was made in the report.

1.12 Wreckage

The aircraft first struck some trees located 1 060 m (3 480 ft) from the south end of Runway 19. The tree tops were about 55.5 m (183 ft) above mean sea level and their height above the south end of Runway 19 was 26 m (86 ft).

During the impact about 1.5 m (5 ft) of the tree tips were clipped. The length of the wreckage trail was about 490 m (1 610 ft) and its width varied between 8 and 65 m (26 to 215 ft).

Cuts in the spruce and pine trees indicated that, at initial impact the aircraft was descending at an angle of approximately 3°, and that in the following 90 m it reached a bank angle to the right of approximately 20°.

The aircraft then travelled in an area free from trees, about 70 m in length, and after that encountered some trees. The cuts in the trees indicated a down slope of about 6° and a bank angle to the right of 30°. Between 200 m and 400 m after the point of initial impact there were only small trees and a marsh. The clipped right wing collided with the ground approximately 250 m after the point of initial impact and the aircraft started to disintegrate; the main parts of the wreckage were found between 410 and 490 m after the point of initial impact. (See Fig. 2-2.)

Due to the risk of snowfall the various parts of the wreckage were located, measured, marked and photographed immediately after the first inspection of the accident area. The ground was covered by 35 cm (14 in) of snow and therefore several pieces were found after the snow had melted.

The interior, the emergency equipment and the fuselage, as well as the spare parts that were loaded in the lower cargo holds, were transported to a store house within Arlanda airport area.

The engines were lifted from the accident area on 17 January by a helicopter to a nearby road and then transported to a workshop for technical examination.

All instruments were taken out of the cockpit after registration and were transported to Arlanda for preliminary checks, and then to a workshop for final inspections and tests. The other parts of the wreckage were transported to a hangar for visual inspection.

No evidence of structural failure prior to the initial impact with trees was found. It was determined that at the time of initial impact the undercarriage was retracted, the flaps were at a setting of 27 degrees, the leading edge flaps were extended, the stabilizer was at a setting of 3 degrees nose-up and that engines Nos. 1, 2 and 3 were operating at more than 92 per cent of the full power, probably at full power.

The thrust reversers of the engines were fully retracted and the actuators for the inner spoilers were found in position for normal operation, indicating that the ground spoiler control lever was positioned on "NORM".

The flight control systems, the various components of the hydraulic system, the electrical system, communication and radio navigation systems, landing gear and wheels including brakes and bearings, did not reveal any other failures than those originating from the impact.

The investigation revealed that the vertical gyro of the pilot-in-command had been repaired because of an overload or short circuit in the electrical unit. The repair, which possibly had occurred before the delivery of the aircraft to Spantax SA, consisted of a wire being installed between two connecting points as a substitute for an overloaded and burnt wire in a large electrical harness. The Commission found several wires in the assembly seriously damaged, the damage being caused by the faulty wire. As a consequence of these findings the Commission made a special investigation to determine the kind and degree of the damage to see the effect it could have had on the attitude indicator. The investigation clearly showed that no malfunction in the unit could have been caused by the damaged wires.

Additionally the Commission found that the signal output of the pilot-in-command's vertical gyro caused an error in the attitude indicator. The error gave an indication of 4^{o} bank to the left, when the gyro was horizontal. Examination showed that this error was caused by a locking nut that normally holds the synchro transmitter in correct position. This locking nut was not properly tightened, allowing the rotor to move around its axis. The force needed to turn the rotor, however, was found to be so great, that the rotation in all probability occurred at impact. Also according to the co-pilot no indication differences were observed when he checked the instruments before take-off.

A discrepancy was found in the auto pilot rudder servo unit, in which a locking tab and a retaining ring became loose at some undertermined time, causing some friction into the rudder system. However, that friction was negligible compared to the normal pedal forces.

1.13 Medical and pathological information

None mentioned in the report.

1.14 Fire

There was no fire.

1.15 Survival, search and rescue

When the Tower controller did not receive any answer to his radio calls after the take-off an uncertainty phase was declared. After further radio calls without any answer the controller alarmed the rescue units at 2228 hours.

The search commenced on the field and in the take-off sector close to the field without results and was gradually extended up to a distance of approximately 3-4 NM.

The surviving crew members managed to locate and operate the portable emergency transceiver carried on board the aircraft. Radio contact was established at 0114 hours between the accident site and the tower. The crew informed the tower of the situation but was, due to complete darkness, unable to give information about the surroundings that could facilitate a location of the site. On the Direction Finder (VDR) in the tower it was impossible to get a stable bearing to the emergency transmitter (± 15°) and the accident site was not located until 0227 hours, i.e. 4 hours after the accident occurred.

The extensive damage sustained by the cabin area of the aircraft left very limited possibilities of survival. However, the cockpit area of the aircraft incurred comparatively limited damage. The pilot-in-command acquired severe cold injuries on hands and feet and minor contusions. The co-pilot was squeezed tight in the cockpit and could not be freed until about 8 hours after the crash. He sustained a complicated fracture of the right tibia and fibula and severe injuries of legs and hands from compression and exposure to cold. Subsequently he suffered partial amputation of both feet and several fingers. The flight engineer acquired a compression of the thorax. The ground engineer broke one leg close to the ankle and the surviving air hostess received minor contusions.

In view of the time needed by the search and rescue units to find the accident site and to get the co-pilot out of the cockpit, the Commission made a close examination of the organization and working principles of the search and rescue units at Arlanda.

This examination revealed shortcomings in preplanning, equipment and personnel resources which were reported to the Swedish Government in February and December 1970. They were briefly as follows:

(i) The alarming of the search and rescue units did not function satisfactorily. This was due to the fact that the rescue plan only contained instructions for the guard how to alert and inform the units when the accident site was known. Instructions for alerting, informing and ordering the units when the accident site was unknown did not exist. This unforeseen alternative created difficulties and delayed the alarm. The search was not conducted in a well preplanned and organized way. No comprehensive exercises in searching had been held which could have disclosed the deficiencies at an earlier stage.

(ii) The rescue work in the wreckage was prolonged due to lack of knowledge of the aircraft and inadequate technique when cutting the aircraft skin. No portable electrical equipment sufficient for heating and lighting was available.

(iii) The Commission also found reason to reconsider the composition of the search and rescue crew in order to increase its efficiency. In the special reports the Commission recommended that immediate steps should be taken in order to increase the efficiency of the search and rescue service at Arlanda and also to review such service at other airports.

1.16 Test and research

No special flight test was conducted.

1.17 Three-engine ferry flight procedures

When planning operations the operator must consider the operational procedures established by the aviation authorities of the State of Manufacture and align its own instructions to pilots with these established procedures; special company rules may be established usually after approval from the State of Registry.

The Convair 990 was approved for 3-engine ferry flights by the U.S. Federal Aviation Administration in accordance with the requirements in Civil Aviation Regulations (CAR 1.77) and the limitations and operating procedures in Supplement A to the Approved Airplane Flight Manual stated, *inter alia*:

(a) Flight crew

No persons other than required members of the flight crew shall be carried on board during this type of operation.

(b) Weight limitations

The maximum allowable take-off gross weight for this type of operation is limited by the chart on page Sup A-3. The operating weight on individual flights must be limited to the minimum weight necessary for the particular ferry flight.

(c) Take-off procedure

Detailed instructions regarding the handling of the aircraft during take-off were also given in that supplement and the performance calculations were based on a flap configuration of 10°.

The Operator's Chief Pilot/CV 990 informed the Commission that Spantax SA used the take-off procedure laid down in the manual. All pilots-in-command in the company were trained in 3-engine take-offs. The take-off weather minima were equal to landing weather minima at day and night. No tail wind restrictions or runway conditions were specified. In this connexion it was noted that the U.S. FAA operational requirements regarding 3-engine ferry flights valid for U.S. operators (FAR 91) stated that take-off shall be performed on a dry runway, unless permission for take-off on a wet runway is specifically mentioned, and that the weather conditions at both the point of departure and that of destination shall permit flying in accordance to Visual Flight Rules (VFR).

The pilot-in-command and the co-pilot claimed that the 3-engine take-off procedures of Spantax SA at the time of the accident allowed the pilots to use either the 10° or 27° flap setting. On 9 January 1970 the Company Chief Pilot/CV 990 stated that pilots were allowed to use 27° flap setting for such take-offs according their own judgement. In a letter dated 27 October 1970 the Chief Pilot informed the Commission that the regulations in Supplement A to the approved Aircraft Flight Manual regarding flap setting were adhered to. On 3 December 1970 the Manager of Operation also stated that no flap setting other than 10° was allowed for 3-engine take-offs and presented a circular to pilots, dated 22 April 1969, to this effect. The use of 10° or 27° of flaps was not considered of importance in the accident and therefore the Commission decided not to look further into this subject, considering that should further investigation in this matter appear desirable it should be carried out by the Spanish aviation authorities.

The Chief Pilot further stated that cabin crew members were considered as flight crew members, according to Spanish Regulations.

2.- Analysis and Conclusions

2.1 Analysis

The U.S. FAA-approved Airplane Flight Manual stated that 3-engine ferry flights are authorized on CV 990 provided the operational requirements in Supplement A to the manual are met.

The flight manual stated that the number of flight crew members should be limited to those required for the actual flight. The Commission considered that this requirement was not met since in its opinion the flight crew should have only consisted of the pilot-in-command, the co-pilot and the flight engineer.

Furthermore, the flight manual stated that the operating weight shall be the lowest possible. The loadsheet for the flight Arlanda - Zurich showed a fuel consumption of 50 000 lb, the same as that calculated for the previous flight Arlanda - Palma de Mallorca. According to the calculations made by the Commission, the fuel consumption between Arlanda and Zurich should have been 30 000 lb only and therefore 20 000 lb should have been de-fuelled before take-off. This weight reduction was equivalent to a decrease of the required runway length of about 500 m and an improvement of about 2.4 per cent in the climb gradient (from 5.6 per cent to 8 per cent).

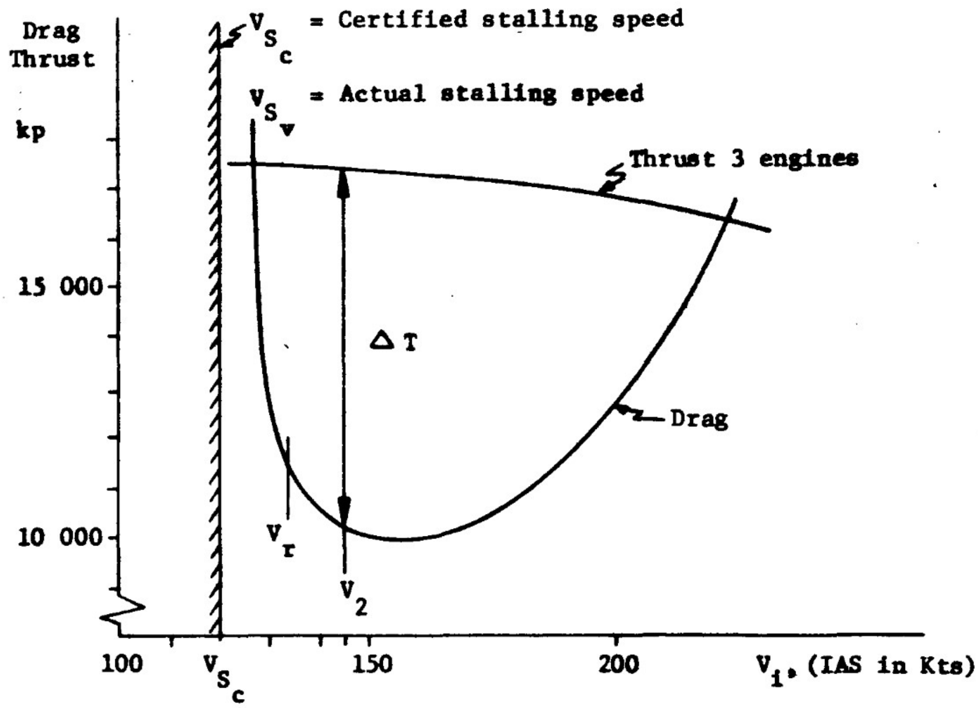
The flight manual also stated that the flap setting should be 10°; however, the flaps were set at 27°. This setting gave a take-off run about 30 m shorter that that with a 10° flap setting but reduced the climb performance. If 10° flap setting had been used, an increase of 3.0 per cent in the climb would have been obtained (from 5.6 per cent to 8.6 per cent) not taking the effect of weight reduction into account.

Thus, there were two possibilities for the pilot-in-command to improve the performance of the aircraft. Inadequate information regarding the above-mentioned factors on the performance of the aircraft may explain why these possibilities were not utilized. The actual take-off weight, however, was well below the maximum authorized under existing conditions. The climb gradient was 5.6 per cent with flap 27° and as the lowest allowable climb gradient was 3 per cent (FAR 91 91.45) the performance requirements were fulfilled.

If the weight had been decreased and a flap setting of 10° had been used the margin to stall (V_{sv}) would have been the same but the margin to minimum control speed (V_{mc}) would have decreased. It was therefore the opinion of the Commission that the actual weight and flap setting were not contributing factors to this accident. However, the operator, if it wished to permit a 27° flap setting configuration for 3-engine take-off should have included in the Aeroplane Flight Manual the calculations required to establish maximum take-off weight with respect to available runway length. Such data should then have been approved by the Spanish CAA before being used.

Several meteorological phenomena which existed at the time of take-off were found to be of significance in this accident. Firstly, because of patches of ice at the beginning of the runway the aircraft was taxiied a short distance before the take-off was commenced. Secondly, patches of ice on the runway encountered during the take-off roll, reduced the capability of the nose wheel to withstand side forces and thus to compensate for asymmetric thrust. Therefore the pilot-in-command had to reduce and thereafter slowly increase the power on No. 1 engine during the first part of the take-off run. The acceleration up to about 100 kt was made by means of engines Nos. 2 and 3 at 100 per cent take-off EPR, while average thrust on No. 1 engine was about 50 per cent only. The take-off run was therefore increased from 2 000 m to about 2 300 m and, allowing 200 m for the initial taxiing, the lift-off took place after approximately 2 500 m of the available runway length had been used.

The foregoing situation is worthy of attention when considering the performance and aerodynamics of the aircraft. The drag curve of the Convair Coronado CV 990 in the actual configuration present in this accident (take-off weight and flap setting) is illustrated as follows:

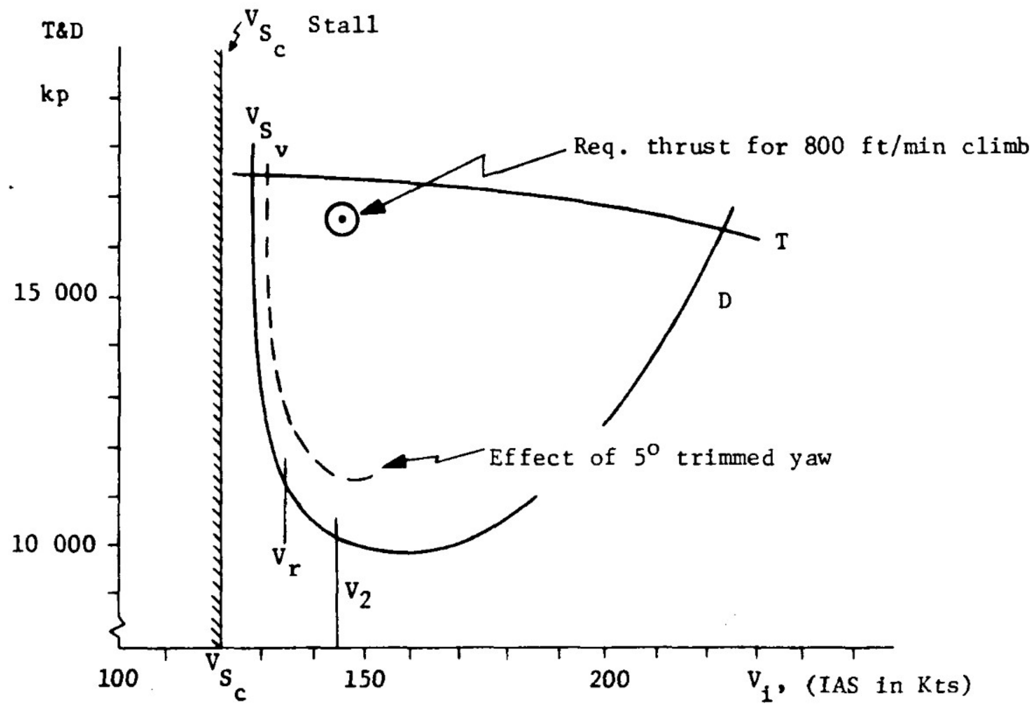


△T = Excess thrust (climb/acceleration)

The chart shows drag and thrust vs speed. The effect of the landing gear and trimmed yaw is not included. The chart illustrates two stall speeds. The lowest one, V_{SC}, is the one obtained during normal certification flight, when the flight path is somewhat curved so that the load factor is less than one. (When the flight path is negatively curved the wingload will be reduced, resulting in a lower stall speed than that obtained in level flight.) The real stall speed is shown by V_{SV}. According to the certification regulations, the climb-out speed (V_2) must not be less than 1.2 V_{SC}. As shown in the chart, the margin above actual stall is lower. Furthermore, the climb-out speed lies within that area where the drag increases considerably when the speed is reduced, which implies high stall risk.

Thirdly, at the time of lift-off, the visibility was reduced by patches of cloud at the far end of the runway. Furthermore, the pilot-in-command reported that he was almost blinded by the illumination of the clouds from his landing lights. During the transition from flying with visual reference to flying on instruments he had no immediate control of the aircraft attitude. In a 3-engine take-off it is almost impossible to apply correct rudder by feeling only, especially if the bank angle or speed is changed. Therefore, it is very probable that the aircraft started a yaw to the right immediately after lift-off. This is supported by the fact that the site of impact is to the right of the centre line of the runway. It should be noted that, for this type of aircraft, the ability of the rudder to counteract a turn towards the "dead" engine is strongly affected by the bank angle of the aircraft. Banking about 5° towards the dead engine means that application of full rudder is not enough to stop a turn to the right unless the airspeed is increased.

A yawed condition just after lift-off may have a large effect on drag. The first thing to happen when a swept wing aircraft yaws is that the lift on the wing "moving forwards" increases and the lift on the wing "moving backwards" decreases. The resulting effect is a rolling moment that has to be counteracted by applying spoilers/aileron. A combination of spoiler deflection and trimmed yaw results in a considerable drag increase. Furthermore, maximum attainable lift will decrease on the wing "moving backwards" as a result of increased disturbances of the airflow around the engine pylons at the wing leading edge and also as a result of increased spanwise boundary layer flow. At the same time, as the lateral control spoiler goes up, the maximum lift of the wing "moving forwards" decreases. Thus, increased drag is obtained in combination with decreased maximum lift, and the margin to stall decreases. An illustration of the effect of a trimmed 5° yaw is shown in the following chart:



In referring to this chart it should be noted that the increase of drag and stalling speed is based on somewhat uncertain wind tunnel data and that the effect may be greater than shown. If the 5° yaw was combined with a 5° bank to the right, the result would have been a turn that, on the whole, agrees with the site of impact. This does not mean that the side-slip and consequently the spoiler deflection may not have varied during the climb, and the increased drag may at times have been greater than shown in the chart.

If the thrust required to climb at 800 ft/min (rate-of-climb according to the pilot-in-command) is added to the drag of the aircraft trimmed at a 5° yaw there remains almost no thrust for acceleration after lift-off, especially if one considers the extra drag from a retracting landing gear. Therefore, it is very probable that the aircraft after lift-off was in a climb without any acceleration and with a poor margin to critical speed. The available margin would decrease rapidly if there was any violent yaw in combination with a spoiler deflection.

Fourthly, there was a marked temperature inversion, the temperature increasing by about 10°C between ground level and a height of 170 ft above the ground. As a result the thrust decreased by about 4 per cent and the IAS decreased by about 3 kt which again reduced the margin to stall.

Fifthly, there was some wind shear the exact magnitude of which could not be determined. However, the presence of the wind shear, particularly in combination with the above-stated circumstances, may have had a determining effect. From a fairly steady state in climb, a sudden tailwind of 5-10 kt may have placed the aircraft in a position of a large thrust deficit. The only chance to get out of this situation would have been to immediately reduce the angle of attack. Probably the flight crew did not discover the effect of the wind shear in time due to the workload and the control difficulties encountered during the take-off. The possibility for the co-pilot to maintain a proper watch of the instrument panel was impaired by the radio call from the Tower immediately after lift-off.

The possibility of engine icing was also considered by the Commission but it was concluded that in the prevailing circumstances it was highly improbable that icing could have contributed to the accident.

The Commission considered that the most probable course of events was as follows. Because of ice patches the take-off was not commenced from the end of the runway: the take-off run was then extended beyond that planned because of the need to reduce power on No. 1 engine to maintain directional control. Immediately after lift-off, when flying by external visual reference, the pilot-in-command was blinded by reflection of the landing lights from low cloud.

During the transition period to instruments the pilot-in-command did not observe that the asymmetric thrust had initiated a yaw to the right. This yaw would have led to a rolling movement to the right which must have been counteracted by left spoiler/aileron deflection. This would have tended to increase the drag and the yaw would have increased; at the same time the roll or bank angle to the right towards the "dead" engine meant that the pilot-in-command was no longer able to control the turn to the right.

Co-incident with the foregoing events the aircraft encountered increasing air temperature, therefore the engine thrust decreased as well as the indicated airspeed. At the same time the aircraft climbed from nil wind into a tail wind. These factors, combined with the drag due to yaw, resulted in deceleration of the aircraft and a further increase in induced drag until a large thrust deficiency was present. There was no time to adjust the engine power and the loss of airspeed could not be compensated for by assuming a change of aircraft attitude because of insufficient height. The aircraft then descended in a right turn and struck the trees.

2.2 Conclusion

(a) Findings

The Certificate of Airworthiness of the aircraft, issued by the Spanish CAA, was valid.

Pre-flight check was performed without remarks.

The vertical gyro of the pilot-in-command had been repaired, possibly before the aircraft came in the ownership of Spantax SA, and this had not been properly done.

A retaining ring in the rudder servo unit of the aircraft had come loose, probably before the accident.

The Flight Data Recorder was not operating satisfactorily at the time of the accident nor during the previous flights.

No technical failures or malfunctions were revealed that could have caused or contributed to the accident.

The aircraft was loaded within the C G limits.

The maximum take-off weight was not reduced to the lowest possible to meet the requirements stipulated in the approved Aircraft Flight Manual. However, the take-off weight was below the maximum possible for a 3-engine take-off.

The flight crew was properly certificated by the Spanish CAA, and all had passed their periodical flight training within prescribed periods and also their medical checks without remarks.

The total number of crew members had not been reduced to the minimum required for such a flight.

Flap setting during take-off was 27°.

Spantax SA prescribes that the weather conditions shall be equal to or better than landing minima in order to perform a 3-engine take-off, night or day. No specific requirements on runway conditions or on maximum permitted tail wind component are cited.

Patches of ice on the runway reduced the friction and thereby the capability of the nose wheel to take up side forces. During acceleration to 100 kt, the average thrust used on engine No. 1 was probably 50 per cent. Full power on all three engines was, however, set well below V_1.

There was a marked temperature inversion in the air close to the ground.

There was a wind shear. The wind was reported calm at surface but was blowing from the NNW at 5-10 kt at 30-50 ft producing a tail wind component for aircraft taking off on Runway 19.

The crew was not informed about the temperature inversion and wind shear.

Neither the actual weather reports nor the forecast for Arlanda contained any information about the possibility that the existing low clouds of stratus would be as low as 30-50 ft above the far end of Runway 19 and in the climb out area.

These clouds were illuminated by the landing lights and possibly by the approach lights to Runway 01, which blinded the pilot forcing him to change to instrument flying earlier than could have been expected.

During the climb-out, the co-pilot was requested by the Tower to change radio frequency. This preoccupation diverted his attention from his primary duty of watching the instrument panel.

The entire movement of the aircraft on runway and the initial climb could not be observed from Tower.

(b) Cause or Probable cause(s)

During a 3-engine take-off the aircraft entered an uncontrollable attitude with increased drag and decreased indicated airspeed owing to the following combined circumstances:

Unexpected, early loss of external visual references after lift off. During transition from visual to instrument flying the pilot lost directional control, this again resulting in increased drag due to yaw. The presence of a temperature inversion reducing thrust and indicated airspeed.

The presence of wind shear causing further decrease of indicated airspeed, which resulted in large drag increase.

3.- Recommendations

1. Civil Aviation Authorities are recommended to approve no lower weather minima for 3-engine take-offs than those required for circling and to issue instructions concerning runway conditions. No 3-engine take-off should be allowed in darkness or in tail wind.

2. The Operator should instruct the flight crews thoroughly about the aerodynamics of the aircraft in different configurations. Special attention should be given to drag as a function of airspeed, and to factors affecting V_{mc}.

3. The Operator should enforce procedures to ensure proper operation of the Flight Data Recorder.

4. In addition to recommendations with respect to the rescue organization as rendered in separate reports, the Commission recommends that aircraft emergency and rescue equipment be reviewed.

5. The flight crews should be briefed about observed or expected extreme temperature inversions at low levels.

6. Until clear international criteria have been established for measuring and reporting wind shear at low levels, such information, when the existence is known, should be given by the meteorological office to ATC particularly in cases when it could affect the determination of runway for take-off and landing. Operators should inform flight crew about the effect of wind shear. This same information should also be given, in an appropriate way, to air traffic controllers and weather officers.

7. In order not to disturb the crew during the climb-out, ATC should instruct departing aircraft, before take-off, on the frequencies to be used after becoming airborne.

8. The possibilities to equip ATC with means to observe aircraft movements on and close to airports in reduced visibility should be investigated.

9. The effect of using approach lights on runway opposite the take-off direction should be evaluated.

4.- Action Taken

In view of the observations made with regard to the repair of the pilot-in-command's vertical gyro and also the loosened retaining ring in the rudder servo unit of the auto-pilot, the Commission has, according to the Aviation Law, in separate communication to the Spanish and to the Swedish CAA, reported these findings for the actions deemed necessary by the Authorities.

Certain aerodynamic characteristics and their operational implication on modern jets seem not to be sufficiently substantiated. Therefore the Commission in a separate communication to the Swedish CAA has expressed the need for further evaluation and possible initiation of international tests and analyses of the following items:

(a) effect of yaw and spoiler deflection on drag and stall speed at high angles of attack;

(b) the size of the speed margin between V_{mc} and V_2 during the dynamic progress of a 3-engine take-off and normal take-off with critical engine failure at V_1.

Comments of the State of Registry of the aircraft (Spain)

1. Section 1, sub-section 1.1 History of the flight, second paragraph - last two sentences.

It was known in Arlanda that the Coronado EC-BNM had aborted take-off at 1758 hours owing to failure of No. 4 engine and had disembarked its passengers, who were embarked on another aeroplane. Accordingly, the Coronado was, of necessity, empty during the second take-off at 2220 hours.

A statement was taken from the co-pilot in the Academic Hospital on 10 January 1970 at 1500 hours. According to the information taken down verbatim Mr. Granado declared that he had communicated the amended flight plan (Zurich instead of Palma) to ATC at 2208 hours and requested thereafter clearance to start up the engines and taxi, together with take-off information. TWR gave the clearance and assigned runway 08 for take-off. Responding to this assignation, the co-pilot reported that the flight was a "Ferry Special" and requested runway 19. Since there was zero wind, it is clear that if the co-pilot declined runway 08 and requested the longer runway 19 it was on account of the extra distance required to take off on three engines.

2. Section 2, sub-section 2.1 Analysis, sixth paragraph - last two sentences.

The Spanish Representative disagreed with the inclusion of this paragraph from the very beginning.

At the meeting in Stockholm on 3 December 1970 it was pointed out that the Coronado Convair CV 990 had been certificated in Spain by the Under-Secretariat of Civil Aviation with the same specifications as in the USA; i.e. there can be no two opinions as to whether the Spanish Civil Aeronautics Administration should or should not approve the requirement for take-off with one engine out and 27° flaps, since the only configuration approved in Spain for take-off with three engines operating is the original one of the Convair 990, namely, with 10° flaps (FAA - CCAR 1.77 and Supplement A to the Aeroplane Manual).

ICAO Ref: AIG/001/70

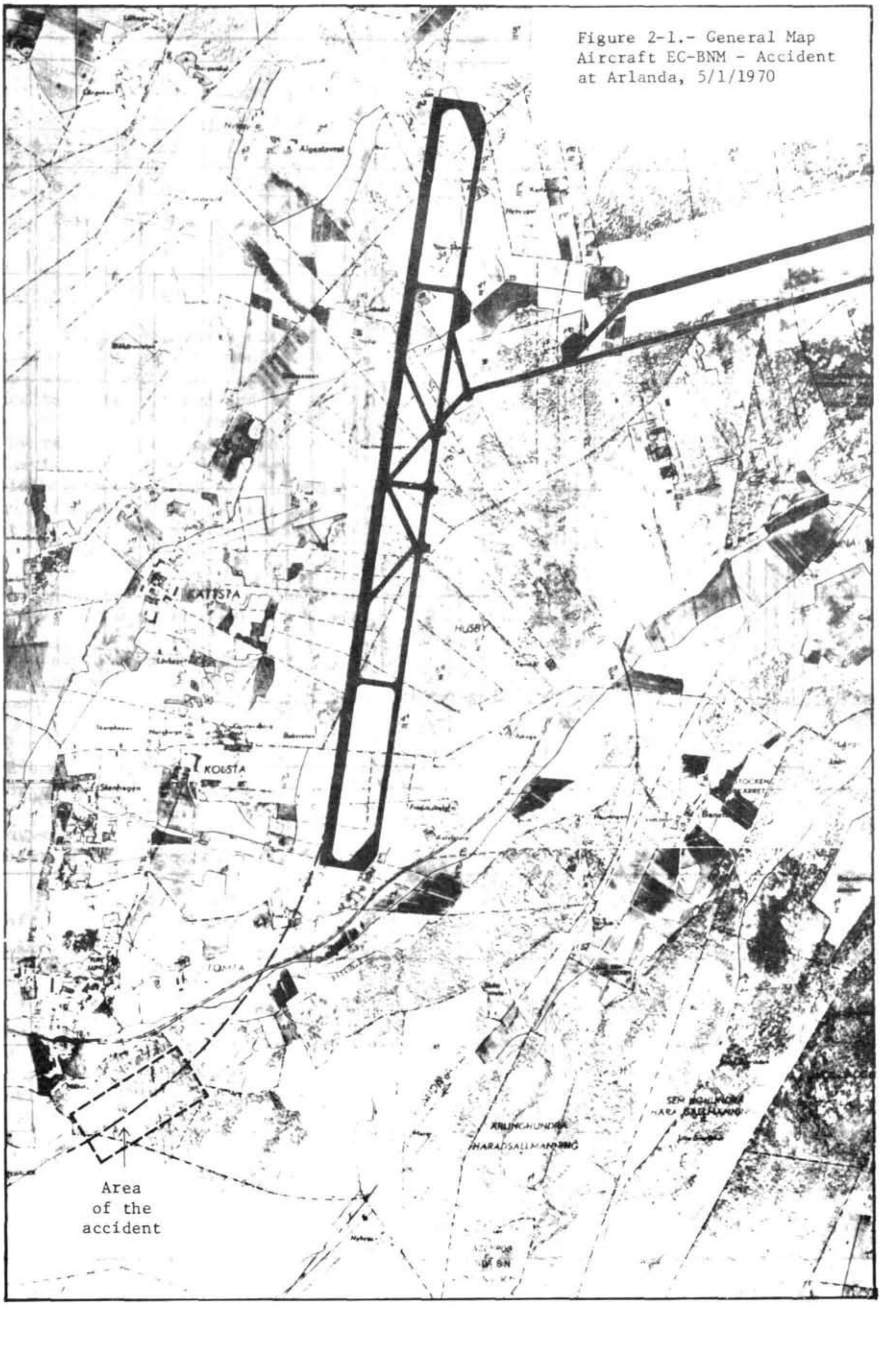


Figure 2-1.- General Map
Aircraft EC-BNM - Accident
at Arlanda, 5/1/1970

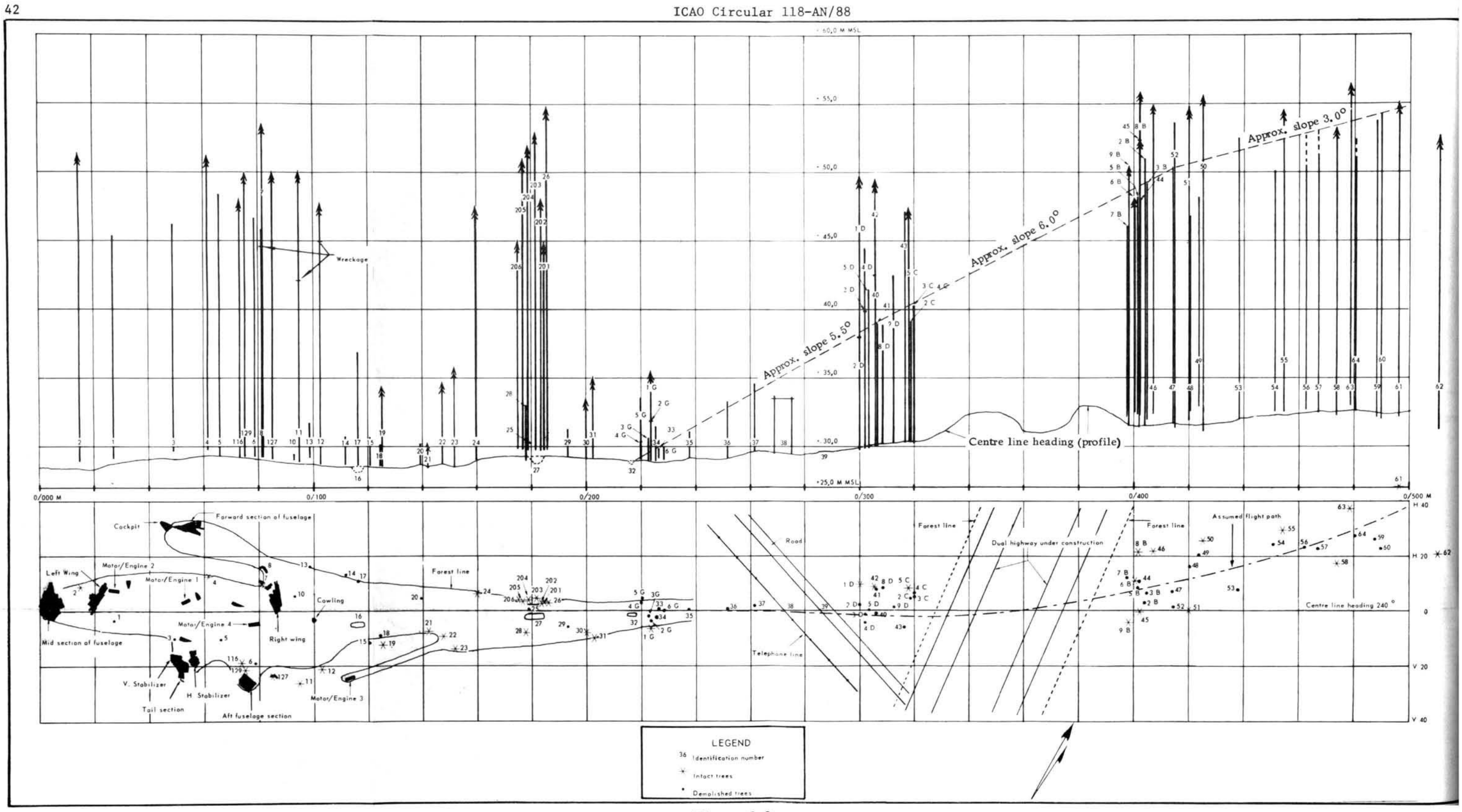

+60,0 M MSL
+55,0
+50,0
+45,0
40,0
+35,0
+30,0
+25,0 M MSL
Wreckage
Approx. slope 5.5°
Approx. slope 6.0°
Approx. slope 3.0°
Centre line heading (profile)
0/000 M
0/100
0/200
0/300
0/400
0/500 M
Cockpit
Forward section of fuselage
Left Wing
Motor/Engine 2
Motor/Engine 1
Motor/Engine 4
Motor/Engine 3
Cowling
Right wing
Mid section of fuselage
V. Stabilizer
H. Stabilizer
Tail section
Aft fuselage section
Forest line
Road
Telephone line
Dual highway under construction
Assumed flight path
Centre line heading 240°
H 40
H 20
V 20
V 40
LEGEND
36 Identification number
Intact trees
Demolished trees

Figure 2-2