No. 18

Lufthansa, Boeing 747, D-ABYD, accident at Nairobi, Kenya, on 20 November 1974.
Report No. CAV/ACC/26/74, dated July 1976, released by the
Accident Investigation Branch, East African Community.

1.- Investigation

1.1 History of the flight

Introduction

The aircraft was on a scheduled international passenger and cargo flight (LH 540/19) originating in Frankfurt, Federal Republic of Germany, and with intended stops at Nairobi, Kenya, and Johannesburg, South Africa. A change of flight deck and cabin crew was scheduled at Nairobi.

The flight from Frankfurt was routine, and the aircraft arrived at Nairobi at 0357 hours. The crew reported there were no defects, and in due course went off duty.

Pre-flight phase

The aircraft was refuelled up to 61 000 kg of fuel, resulting in an estimated take-off weight of 254 576 kg. Because this figure was well below the maximum authorized for the forecast take-off conditions, the take-off from Nairobi was planned on a reduced engine power basis ("-3A power"), using the following parameters:

Runway in use	06
V_1	125 kt IAS
V_R	138 kt IAS
V_2	148 kt IAS
Stabilizer trim setting	5.2
Rotation target attitude	14^o
Take-off EPR (-3A power)	1.46
Take-off EPR (-7 power)	1.51*

*This figure is routinely calculated and is available for use in case of engine failure or other emergency when extra power is required. During the Before Start checks it is set on the No. 4 EPR gauge bug.

The Pilot-in-command of the relieving crew designated his co-pilot as handling pilot for the sector. In due course the co-pilot, sitting in the right hand pilot's seat, read the Cockpit Checklist and the Before Start Checklist, with the appropriate crew member responding. The flight crew spoke amongst themselves without the use of the aircraft's intercommunication (interphone) system. For radio (RTF) communications they used their head-sets and hand-held microphones. At 0442 hours the engines were started in accordance with a revised procedure introduced by the Company the previous year. This required that the bleed air valve switches which control the aircraft's pneumatic system supply remain in the closed position until after the engines had been started. When the starting sequence was complete the co-pilot read the After-Start Checklist, which contained, *inter alia*, specific reference to confirmation that the bleed valves switches had been selected OPEN. The crew afterwards stated that up to this time, and indeed throughout the flight, the checklists were accomplished correctly and without undue haste.

The taxiing phase

At 0447 hours, the co-pilot requested taxi clearance, and the control tower cleared the aircraft to Runway 06.

Shortly afterwards the tower controller called the flight again, offering a choice of Runways 24 or 06. As he was aware that the aircraft was well below its limiting take-off weight for either runway and that the wind was light, the Pilot-in-command elected to use Runway 24, which would give a shorter flight path to intercept the initial track to Johannesburg. The crew considered that the change of runway would not materially alter their take-off data and they therefore did not recalculate it.

In order to reach the Runway 24 take-off point the Pilot-in-command had to taxi the aircraft down taxiway "C" and back-track the runway in use (see Appendix 1). Whilst the aircraft was on Taxiway "C" the co-pilot selected the flaps to the 10° take-off position. Shortly afterwards the flight engineer started to read the taxiing Checklist sitting facing forwards and with his seat in the forward position. At 0451 hours, just after the checklist had been completed, the control tower passed the flight its Air Traffic Control (ATC) clearance. At the same time the Pilot-in-command turned the aircraft at the end of the runway. The flight engineer then read the Take-off Checklist. At 0452 hours, take-off clearance was received from the control tower, the surface wind being reported as calm.

The take-off run

The Pilot-in-command partially opened the throttles to initiate the take-off and the co-pilot took control of the nose-wheel steering. The flight engineer then adjusted the throttles to set the correct, -3A, take-off power of 1.46 EPR. At the call of "80" (80 kt IAS) he relinquished control of the throttles to the Pilot-in-command but continued to face forwards whilst monitoring the engine instruments on the pilots' centre panel. The co-pilot stated that shortly before target rotation speed (V_R) he released his forward pressure on the control column and then commenced the initial rotation to approximately 10°. Flight recorder data indicates that rotation commenced at 135-136 kt and that rotation rate appeared to be normal. Eyewitnesses estimated the rotation point at between 2 165 and 2 400 m from the beginning of the runway.

During the rotation phase the acceleration, which up to that time had been normal, ceased abruptly. Lift-off occurred at approximately 145 kt, some 35 seconds before the time of first main impact, i.e. I-35. The observed lift-off point was between 2 305 and 2 500 m from the beginning of the runway. As the aircraft was lifting off, all three crew members noticed birds passing by the nose.

The airborne phase

Very shortly afterwards buffeting or "vibration" was experienced and the Pilot-in-command turned to the flight engineer to ask him if there were any indications of abnormal engine vibration. The flight engineer looked back at his panel to check the engine vibration meters and warning lights and confirmed that all was normal. On hearing this the Pilot-in-command thought that the vibration might be the result of unbalanced wheels. He therefore checked that a positive rate of climb was indicated and (at I-21) selected GEAR UP. The co-pilot reported that after becoming airborne he lost all feeling of acceleration such as during the normal take-off, and that he had to lower the nose and gradually descend in order to prevent the airspeed from deteriorating. At no time, in his opinion, had the pitch attitude exceeded approximately 12°.

The flight recorder trace indicates that at I-19 when the aircraft reached approximately 100 ft above ground level, the rate of climb, which had initially been 400-500 ft per minute, fell rapidly to zero, and the aircraft started a gradual descent.

The recording also shows that after reaching a maximum value of some 146 kt just before lift-off, the airspeed thereafter fell slightly, remaining within the range 145 to 140 kt IAS until just before impact*. At I-15 the flight engineer again confirmed that the engines were running normally. At I-8, as the speed decayed to 140 kt, the stick shaker operated for three seconds. The Pilot-in-command immediately put his hands on the control column to lower the nose, but was unable to lower it appreciably because of the proximity of the ground. After a 2 second pause the stick shaker recommended operation, and at I-1 the landing gear warning horn sounded. Subsequent investigation indicated that the horn had been activated by the action of the co-pilot in closing all four throttles when he realized that impact with the ground was imminent.

The crew stated that, due to anxiety about engine vibration, power was never increased beyond the initial (reduced) take-off power setting. A former airline pilot who was sitting in the left hand window seat at row 16 stated that the take-off run, rotation and lift-off appeared normal. After lift-off, he felt the aircraft shaking and, on looking out of the window, noticed that the wing leading edge flaps were not extended.

Ground impact

The first point of impact occurred when the tail of the aircraft grazed bushes and grass located 1 120 m from the departure end of Runway 24, and some 33 m to the south of the extended centre line. The aircraft continued in a partially airborne condition for an additional 114 m with its tail scraping the ground. It then struck an access road running at right angles to the flight path and protruding to a height of some 8 ft above the surrounding terrain. On impact the tail structure began to disintegrate, but the major part of the aircraft skidded a further 340 m, during the course of which it turned to the left and came to rest facing in the opposite direction. Fire broke out in the left wing and the separated tail section. Shortly afterwards an explosion in the left inner wing spread the flames to the fuselage.

As the aircraft came to a halt the Pilot-in-command pulled the four engine fire switches. After an unsuccessful attempt to open the overhead escape hatch he and the flight engineer eventually escaped through holes in the fuselage side. The co-pilot finally succeeded in opening the escape hatch and lowered himself to the ground by means of the emergency escape reel. He and the Pilot-in-command assisted passengers to escape until forced to leave the main wreckage area by explosions. Due to injury the flight engineer was unable to assist in rescue attempts.

Due to the development of events and the rapid disintegration of the aircraft immediately following initial impact, no evacuation command was heard in the cabin. Accordingly every cabin crew member acted independently on the basis of their instructions at the time of training.

Escape from the left hand side of the cabin was impossible on account of the fierce fire that had developed, but evacuation through doors Nos. 2 and 3 on the right hand side was accomplished. The automatic action of both these doors and the deployment of both escape chutes functioned correctly.

*Note: Airspeed values observed by the crew during the flight were generally several knots higher than those obtained from the flight recorder.

A number of passengers and some cabin crew were thrown out of the cabin as it disintegrated, and some left through fractured openings after the aircraft came to rest. It was reported that determined efforts to open doors Nos. 1 and 4 on the right hand side of the cabin were unsuccessful. During the evacuation the cabin crew continued to assist passengers to leave the wreckage until forced away by the fierceness of the fire.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	4	55	-
Non-fatal	9	45	-
None	4	39	

1.3 Damage to aircraft

The aircraft was destroyed.

ICAO Note: Paragraphs 1.4 to 1.17 not reproduced (the Foreword refers).

2.- Analysis and Conclusions

2.1 Analysis

Introduction

Soon after the accident had occurred, it became apparent that the leading edge flaps were in the fully retracted position at impact. Further investigation suggested the probability that these flaps were incorrectly positioned prior to take-off because the pneumatic supply which powers the leading edge flap units was switched off at the time the flaps were selected to the take-off position.

Apart from the incorrect leading edge flap configuration, there was no evidence of any other primary causal factor.

Crew activities

There seems little doubt that, at the time of the introduction by a number of operators of the revised engine starting procedure which required the pneumatic system bleed valves to be switched to the closed position, the essential role played by these valves in the sequencing of the leading edge flaps was to a certain extent overlooked.

Although the operator's checklists, in common with those of other ATLAS Operators, were amended to include a requirement for the bleed valve switches to be re-opened, and for a check that the VALVE CLOSED indication lights were extinguished, no specific check of pneumatic system pressure was included. In view of the intermittent illumination of the VALVE CLOSED indication lights at low power settings even though the associated bleed valve switches are open, they cannot be regarded as a reliable indication of switch position. Therefore an independent check of system pressure should have been included. However, an experienced crew member, such as the flight engineer of D-ABYB on the accident flight, could have been expected automatically to check system pressure in the normal course of events.

There is no doubt that the flight engineer believed that he had selected the bleed valves OPEN during the After-Start Checks, and he certainly gave the correct response. Nevertheless, in view of the evidence it is difficult to come to any conclusions other than that he must inadvertently have failed to open them.

If he had opened them he must have closed them again within the next two minutes in order to have shut off the pneumatic air supply before the flaps were selected to TAKE-OFF, for the leading edge flap units to be found in the position they were in at impact. In view of the fact that during this time there are no particular actions which have to be carried out by the flight engineer which could be confused with the operation of the four bleed valve switches, this seems unlikely. If one accepts this assumption, it follows that he must also have failed to notice that the four "VALVE CLOSED" amber lights were continuously illuminated and the pneumatic gauge indication of zero duct pressure.

All three crew members presumably believed that they had seen the correct number of leading edge green lights at the time of the Taxiing Checks prior to take-off. In view of the findings of the system analyses that certain single failures could produce an incorrect illumination of the green light on the pilots' panel, sometimes accompanied by one or more of the lights on the flight engineer's annunciator panel, the possibility that each crew member did see at least one green light cannot be excluded. However, the chance of a faulty indication occurring prior to take-off flap selection and not being noticed, or alternatively of its occurring coincidentally with, or just after flap selection, but before the checklist call "FLAPS", must be extremely small. There does nevertheless exist the previous report of just such a case which, however, could not be reproduced. However, if a single fault had existed, the manufacturer's analyses show that a fully correct indication of leading edge flap extension (8 green, no amber lights) could not have been present on the flight engineer's annuciator panel prior to the take-off. It is relevant to note that at this stage the flight engineer would be reading the checklists with his seat in a forward position, following Company practice. His angle of view of the leading edge flap indications at the rear of his panel is such that it is possible to be misled by a quick glance into believing that all eight green lights are on, when in fact they are not ALL on.

The cockpit voice recording confirms that one of the pilots, probably the Pilot-in-command, responded to the call FLAPS, by the words "TEN TEN" followed by another word which could not be understood but which might have been "GREEN". Any other response would have been abnormal and therefore the occasion for comment by other crew members. No response can be heard from the flight engineer, but due to the limitations of the voice recording system the fact that a word or phrase from the checklist cannot be heard in the recording does not necessarily mean that it has not been spoken. It must equally be appreciated that because a correct response to a checklist item has been heard, this cannot be taken as definite confirmation that the check has been physically completed.

At this point, it should be mentioned that although the two pilots are expected to cross-check each other's panels wherever possible, the company manuals made no suggestion of the need for the Pilot-in-command to check any items on the flight engineer's panel before take-off. Therefore on the accident flight the flight engineer had no "back-up" monitoring. Although this philosophy is common to many operators, and is probably acceptable when adequate monitoring facilities of all vital parameters are provided on pilots' panels, in the light of this accident it is suggested that operators should re-examine the validity of their policies in this respect.

Performance considerations

The Pilot-in-command followed normal practice in planning the take-off using reduced engine power in conditions when an adequate performance margin exists. Under the accident conditions the take-off field length available in either runway direction was ample.

Acceleration during the take-off run was normal; there was no evidence of lack of thrust or excessive drag during this phase, and as far as performance was concerned there would have been no indication to the crew that all was not well.

The disparity between eyewitness reports and estimates of the rotation and lift-off points is not considered a significant feature. The probability is that several seconds would have elapsed between the initiation of the manoeuvres and their observation by witnesses situated some distance away, during which time the aircraft would have travelled an appreciable distance.

Analysis of the available data indicates that virtually the whole of the 35-second flight took place in a condition of abnormally high drag and well into the presence of substantial airflow separation; the aircraft was in a condition which can best be described as "partially stalled". It never reached the fully stalled state, which would have been characterized by a greater rate of descent, a lower airspeed reading and, possibly, a change of attitude.

The loss of acceleration during rotation and the subsequent minimal rate of climb resulted from the considerable increase in drag caused by the proximity to the stall of the incorrectly configured aircraft. The discrepancy between recorded airspeed values and those indicated to the pilots could have been due to system errors and would not normally have been significant. However, if the recorded values are correct, they indicate that rotation was initiated slightly early with the result that acceleration ceased at a correspondingly lower value than it would otherwise have done. A study of the low speed characteristics of the aircraft with the leading edge flaps retracted makes clear the extreme sensitivity of rate of climb to airspeed, and in particular that, assuming power and attitude remained unchanged, the aircraft was incapable of emerging from ground effect at any speed below 146 kt IAS. After rotation, the entire flight took place at a recorded airspeed just below this figure. As the aircraft climbed out of ground effect, the handling pilot attempted to maintain or increase airspeed by lowering the nose, but his action was largely ineffective. This may have been partially due to the presence of slightly adverse wind sheer during the climb-out. However, any corrective action he may have taken was nullified by the severity of the drag rise which occurred at about this time (between I-21 and I-10), and which was probably largely due to a further separation of the airflow as the speed fell slightly and the aircraft lost the benefit of ground effect. In addition there was an adverse contribution, believed to be small, from the opening of the landing gear doors during the retraction cycle initiated by the Pilot-in-command at I-21. The possibility cannot be entirely ruled out that in the aircraft's already critical aerodynamic condition the effect on drag of the gear doors was larger than predicted. It was perhaps remarkable that the gear was not fully retracted at the time of impact, 21 seconds later, but tests have shown that without the assistance of the air driven pumps, as would be the case if the pneumatic system was not switched on, this time was not exceptional.

The crew spent the short time available to them in unsuccessfully attempting to diagnose the situation. In view of the two pilots' previous training in approaches to the stall, it seems surprising that they did not recognize the pre-stall buffet for what it was. However, the non-standard configuration and the presence of ground effect may have modified its extent and characteristics compared with those encountered in their normal flight and simulator training. Moreover, they were almost certainly misled by the fact that their attitude and airspeed indications were close to the values they would have expected to see at this stage of the flight. Their target V_2 speed, which included a 20 per margin above the normal configuration stalling speed, was 148 kt. Remembering the birds seen a few seconds earlier, and confronted with vibration and a low rate of climb, they assumed an engine malfunction and made no move to alter the power settings while trying to locate the fault. In spite of their anxiety about engine trouble, it might have been expected that, when the aircraft started to descend, all available power would have been applied. On evidence from the engine manufacturer this would not seriously have affected the engines for at least five minutes. However, analysis of possible recovery actions suggests that even in the first ten seconds of the flight, a decrease in pitch attitude would have been required in addition to an increase in power. This type of reaction was unlikely to have been forthcoming unless the pilots had appreciated that their airspeed was in fact dangerously low. During the succeeding 10-15 seconds, up to approximately I-10, the situation could only have been retrieved by a "stall recovery" type of manoeuvre involving a deliberate loss of height to just above the ground - a desperate action which would only have been attempted if the semi-stalled situation had been identified.

By the time that the stall warning system began to operate (I-8) as the airspeed fell to 140 kt, it was too late to take effective action. This system met the requirements of the Certificating Authority to provide adequate warning of an approaching stall in any standard configuration. It is unreasonable to expect the certification of non-standard configurations. Nevertheless it remains true that had the system installed on the 747 included an input from the leading edge flap position it would on this occasion have operated at about the time of lift-off and should have alerted the crew to the true nature of their problem in time for an effective recovery to be made.

The discrepancy between the onset of stall warning as measured during flight test in free air in the accident configuration and that recorded on the accident flight could be due to several factors including system tolerances, differing rates of approach to the stall, and the presence of ground effect during the relevant part of the accident flight.

The elevated access road could by no means be categorized as an obstruction to the normal take-off flight path, being only 8 ft high and over 1 200 m from the aerodrome; nevertheless the severity of the accident was considerably increased by the aircraft's collision with a protruding obstacle at right angles to the flight path rather than with the otherwise comparatively flat surrounding country.

Historical background

A striking feature of this accident is the number of previous incidents involving the leading edge flaps which are now known to have occurred and which for one reason or another failed to alert the manufacturer, the regulatory authorities or, with very few exceptions, the airlines concerned.

The first Boeing 747 operator to have reported a take-off with the leading edge flaps partially retracted, in August 1972, realized the potential danger sufficiently to alert the manufacturer and the Certificating Authority, and to initiate, in conjunction with the manufacturer, a modification to its own aircraft to include the leading edge flap position in the take-off configuration aural warning system. Both the Certificating Authority and the manufacturer took the view that this was a report of an isolated incident which did not call for any action on their parts because, provided crew drills were correctly followed, there should be no recurrence. In coming to this conclusion they perhaps overlooked the fact that it is the isolated incident which often gives warning of a potentially serious hazard. They must have reached it in the full knowledge that an aircraft with leading edge flaps retracted, taking off at its normal target speed, would have its speed safety margin eroded to the extent that it would be very close to the stall at an altitude where stall recovery was improbable.

Before deciding that no further action was required of them, the manufacturer and the authority concerned should therefore have satisfied themselves beyond all reasonable doubt of the adequacy of the leading edge flap configuration warning system. They should have taken into account, amongst other factors, the fallibility of human beings and the integrity of the system against failure of which they were providing a warning. The fact that the Boeing 747 leading edge flaps are pneumatically powered via electrical sequencing from the hydraulically operated trailing edge flaps might suggest increased possibilities of incorrect operation, compared with a more straightforward arrangement. Following the first reported incident, there occurred eight known incidents involving whole or partial deactivation of the leading edge flap system. In three cases the indication system did alert the crew prior to take-off. However, the continuing recurrence of incidents in spite of warning bulletins from the manufacturer and, no doubt, operators, only emphasized the human fallibility factor and the necessity for an effective warning system as a back-up.

The manufacturer obviously considered the existing warning system to be adequate, because whilst agreeing to the modification proposed by the operator involved in the first reported incident, to include the leading edge flap configuration in the take-off aural warning system, they did not officially mention its existence to other Boeing 747 operators. On all "standard" 747 aircraft, therefore, up to the time of the accident, the only warning of incorrectly positioned leading edge flaps was provided by the absence of a green light on the pilot's centre panel and the absence of one or more of the 8 green lights on the flight engineer's annunciator panel, with the possible addition of amber lights on the engineer's and pilot's panel if the flaps were partially extended.

As a result of the November, 1972, incident in which the crew reported the illumination of the leading edge green light on the pilot's panel although the leading edge flaps has not extended, a study undertaken by the manufacturer showed that this condition could be caused by any one of six separate faults.

Nevertheless, the most recent guidance from the manufacturer on the subject of leading edge flap configuration warning, generally available to operators at the time of the accident, was that contained in the Field Service Memorandum and the subsequent Bulletin of November 1972. These described the incident which had just occurred, and mentioned that the flight engineer's annunciator panel lights had correctly indicated the flap position. The Operations Manual Bulletin merely emphasized cockpit procedural steps, circuit-breaker engagement checks and that the flight engineer's annunciator panel was available "as a supplementary check if desired."

Further evidence relevant to the inadequacy of the leading edge flap indication system as a warning was provided by the series of incidents, reports of which, for one reason or another, never reached the Certificating Authority or the manufacturer until after the accident. It appears that in some cases the operators either did not realize the serious implications of the particular incidents, or else were too embarrassed to report what they perhaps considered as a breakdown in their operating procedures. In other cases the crew themselves were presumably too embarrassed or too afraid of the consequences of reporting their mistakes. It is significant that, after the accident, three reports of successful take-offs with the leading edge flaps retracted filtered through from crews of one operator in a state where mandatory incident reporting is in force. Apparently the mere legal introduction of mandatory reporting of operational incidents is in itself not necessarily effective. Much greater inducements are needed to ensure that crews and operators are not deterred either through embarrassment or fear of the consequences from reporting all incidents which might provide a warning indication for the future. A necessary corollary is that operators, manufacturers and regulatory authorities must have both the will and the capability to sift through the inevitably large number of incoming reports in order to identify potentially hazardous items. Having done so, nothing should be allowed to stand in the way of effective remedial action.

It was unfortunate that the efforts of the operator who reacted positively to the report of a second take-off, where the leading edge flaps were retracted, by attempting to alert the Certificating Authority, were nullified. However, had the warning contained in their letter of August 1974, reached the Certificating Authority, it seems unlikely, in view of their previous somewhat negative attitude to the matter, that action would have been taken in time to affect the course of the accident.

After the report of "incident 3" in November, 1972, Lufthansa, in common with other 747 operators, followed the manufacturer's recommendation to emphasize to crews the necessity to check circuit breaker engagement and adhere to the correct drills. In addition they included in their checklists a check, after flap selection, on the status of the flight engineer's leading edge flap annunciator panel. Unfortunately, due to the inadequacy of the international incident reporting system, operators as well as the manufacturer and the Certificating Authority, were largely unaware of a number of leading edge flap incidents that had occurred subsequently.

The fact that a number of 747 aircraft had previously accomplished successful take-offs with the leading edge flaps wholly or in part retracted is believed to be due to a combination of a number of factors:

1. The effect of altitude, which would be to reduce total engine thrust, and therefore acceleration, at whatever power setting was used. It is believed that the successful take-offs in this configuration were all accomplished at lower altitude airfields than Nairobi.

2. The take-off at Nairobi was made using a reduced engine power setting. This inevitably resulted in a reduced acceleration compared with a take-off using the normal maximum (-7) power setting. However, it has not been possible definitely to establish what levels of power were used on the successful take-offs. The fact that on this occasion the correct reduced power setting was used in accordance with normal procedures, and with an ample power margin for all reasonable contingencies, does not appear to justify a re-examination of the philosophy of carefully regulated use of reduced power settings for take-off.

3. The probable presence of slight adverse wind sheer, i.e. increasing tail-wind component, during the climb-out.

Adequacy of warning/indication systems

Although it seems difficult to believe that the accident take-off could have been made with the bleed valves switched off, necessarily involving failure to notice continuous illumination of the amber bleed valve lights and the lack of pneumatic duct pressure, direct confirmation of this possibility was provided by the incident which occurred exactly seven days before the accident. It is now clear that the indication lights and the positions of the leading edge flaps could be and, on occasion, were being missed. This was because the vital importance of the leading edge flaps and their associated systems had not been sufficiently stressed on the lines of "if these indications are ignored the aircraft could stall on take-off", and above all because the warning of unsafe configuration basically consisted of the ABSENCE of lights. It is recognized that the Boeing 747 has an excellent safety record. Also that, as designed and installed, the leading edge flap lights were only intended to be position indicators, and as such were not included in the master warning or caution panels. However, the correct positioning of the leading edge flaps is almost essential to a successful take-off. In the light of experience it is now clear that correct leading edge flap positioning could not be guaranteed, and therefore that unmistakable warning of an incorrect setting was required. The history of previous incidents in which crews failed to notice that the leading edge flaps were incorrectly positioned confirms that the indication system as fitted to the aircraft at the time of the accident did not meet this requirement, and therefore needed supplementing with a more positive warning device.

When taken in conjunction with agreed improvements to the indication system, the modification endorsed by the Certificating Authority involving the inclusion of the leading edge flap position in the take-off configuration aural warning system, would appear to meet the requirement for an adequate system. However, its effectiveness will on occasion be nullified unless operators remove the take-off warning system from the list of allowable deficiencies, that is to say, make it a "no go" item. In view of the frequency of previous incidents this change is considered essential.

As a further measure, consideration should also be given to the inclusion of leading edge flap position in the stall warning system programme and to the inclusion of a warning, on the pilots' annunciator panel, of low pneumatic duct pressure.

Flight data recorder

Although the accident aircraft's five parameter engraved foil recorder met the current requirements of the state of registry, the quality and quantity of information it provided was not in keeping with the standards expected of aircraft of the Boeing 747 category. On this occasion, other evidence was fortunately available so that the Inquiry was not greatly impeded. However, there is no doubt that for accident investigation purposes the minimum satisfactory standard for all Boeing 747 and similar category aircraft is a multi-channel recorder compatible with ARINC 573 or a similar characteristic.

Cockpit voice recorder

Because the crew did not use the aircraft's intercommunication system for cockpit conversation, three out of the four recorder channels were rendered ineffective and possibly important evidence was lost. Apart from any improvement to the quality of the transcription obtainable from the area microphone channel it appears to be essential that the other three channels should be more fully utilized; for instance by a requirement for the crew to use a "hot microphone" cockpit voice recorder circuit during the take-off, approach and landing phases.

2.2 Conclusions

a) Findings

i) The crew were properly licensed and experienced.

ii) The aircraft had been maintained in accordance with an approved maintenance schedule and its Certificate of Airworthiness was valid.

iii) The weight of the aircraft and its centre of gravity were within the prescribed limits.

iv) The aircraft took off with the leading edge flaps in the retracted position, with the result that it became airborne in a high drag, partially stalled condition.

v) The loss of ground effect during the climb-out together with the probable presence of slight adverse wind sheer and the opening of the landing gear doors during the retraction cycle contributed to a further reduction in performance with the result that the aircraft descended and struck the ground.

vi) Following the introduction of a modified procedure which involved the closing of the pneumatic system bleed valves, the revision of the cockpit checklist after starting was completed did include a requirement for checking the re-opening of the bleed air valve switches but did not specifically call for a check on the pneumatic system.

vii) After the engines had been started the flight engineer omitted to open the bleed valves, thereby rendering inoperative the pneumatic system which powered the leading edge flap units.

viii) The indications of leading edge flap position prior to take-off could not be positively established. However, it is extremely unlikely that the flight engineer's annunciator panel indicated that all the leading edge flap units were in the correct take-off position.

ix) In view of the inherent possibilities of incorrect leading edge flap operation and the critical nature of leading edge position during the take-off phase, adequate warning of incorrect position should have been provided. The existing indication system in use at the time of the accident did not meet this requirement.

x) Cockpit procedures did not call for any cross checking by the Pilot-in-command of items on the flight engineer's panel.

xi) The accident could probably have been averted had the pitch angle been reduced and power been increased sufficiently early in the flight.

xii) The pilots did not take effective recovery action in the short time available to them because they did not identify the semi-stalled condition of the aircraft until alerted by the stall warning system shortly before the aircraft struck the ground.

xiii) The stall warning system did not give adequate warning of the critical condition of the aircraft because it was not programmed to take account of leading edge flap position. Had it been so programmed, its operation at lift-off might have alerted the crew in time to affect a recovery.

xiv) This accident was preventable. Inadequacies in international incident reporting procedures and effective follow-up action could be considered a contributory factor.

b) Cause or
Probable cause(s)

The accident was caused by the crew initiating a take-off with the leading edge flaps retracted, because the pneumatic system which operates them had not been switched on. This resulted in the aircraft becoming airborne in a partially stalled condition which the pilots were unable to identify in the short time available to them for recovery.

Major contributory factors were:

1) the lack of warning of a critical condition of leading edge flap position;

2) the failure of the crew to satisfactorily complete their checklist items.

3.- Recommendations

It is recommended that:

1) The take-off configuration aural warning system programme on Boeing 747 aircraft should be modified to include leading edge flap position.

2) The take-off configuration aural warning system on Boeing 747 aircraft should be excluded from the list of allowable deficiencies.

3) Consideration be given to the incorporation of leading edge flap position in the aircraft's stall warning programme.

4) Consideration be given to the inclusion of a pneumatic duct low pressure warning of the Pilot's Annunciator Panel.

5) Consideration be given to amending operating procedures where necessary to include a cross-check by the Pilot-in-command of important items on the flight engineer's panel.

6) In Boeing 747 and similar aircraft, States of Registry should require the carriage of a multi-channel flight data recorder compatible with ARINC 573 or equivalent characteristic.

7) In Boeing 747 and similar aircraft, consideration should be given by States of Registry to require the installation and use of hot microphone cockpit voice recorder circuits during the take-off, approach and landing phases.

8) Implementation of adequate international incident reporting procedures, as initiated in the Accident/Incident Reporting System (ADREP) of ICAO, including effective follow-up action, should be enforced.

4.- Action taken

The following is a summary of the principal preventative measures taken since the date of the accident:

a) On 23 November 1974, at the request of the Chief Inspector of Accidents, East African Community, and the United States National Transportation Safety Board, the Federal Aviation Administration (FAA) recommended an interim flap inspection procedure. This was to the effect that all Boeing 747 operators should ensure that, prior to leaving the ramp, the flaps should be extended to the normal take-off position and visual confirmation be obtained from a qualified ground observer that all wing leading edge devices were fully extended.

b) On 6 December 1974, the manufacturer telexed all Boeing 747 operators briefly describing the circumstances of the accident and re-emphasizing the necessity for checks on bleed valve switches, leading edge flap circuit breakers and alternate system switches.

c) On 11 December 1974, the FAA issued a "Notice of Proposed Rule Making" proposing an Airworthiness Directive (AD) which would require modifications to the existing leading edge flap indication system and the addition to the take-off aural warning system of an input from the leading edge flap logic unit.

d) On 16 December 1974, the manufacturer suggested alternative modification proposals, as follows:

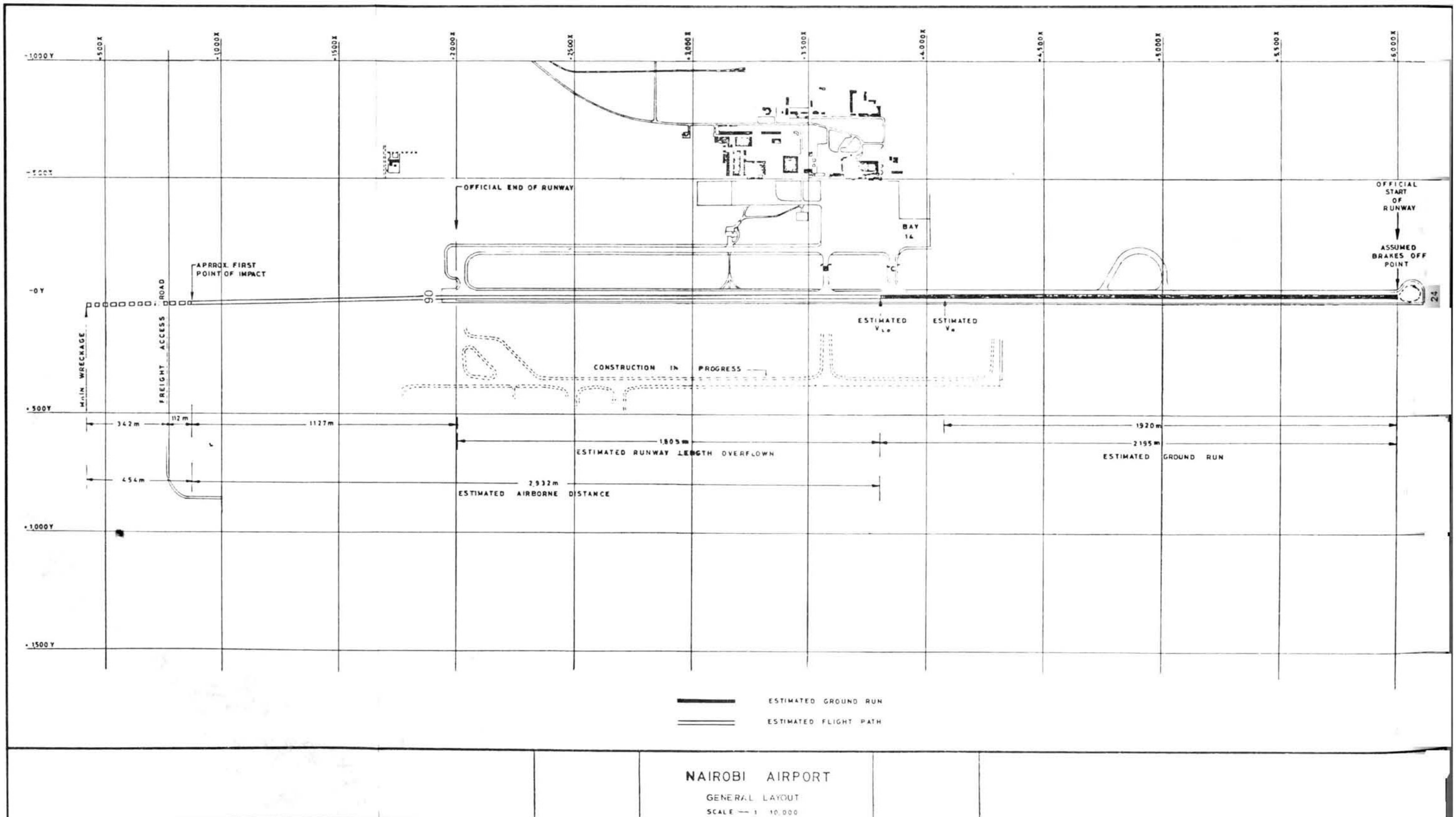
   i) that the amber light on the pilot's panel would light up when any one leading edge flap unit is not fully extended and the trailing edge flaps are at a take-off setting.

   ii) that limit switches in the leading edge flap motors would cause inputs to the take-off aural warning system when any flap unit is not fully extended and the trailing edge flaps are at a take-off setting.

The FAA accepted these proposals and issued an Airworthiness Directive covering the modifications effective 24 March 1975, to be complied with within five months.

ICAO Ref.: AIG/413/74

APPENDIX 1



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-500 Y
-0 Y
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OFFICIAL END OF RUNWAY
OFFICIAL START OF RUNWAY
ASSUMED BRAKES OFF POINT
BAY 14
06
24
APPROX. FIRST POINT OF IMPACT
MAIN WRECKAGE
FREIGHT ACCESS ROAD
ESTIMATED V_{LO}
ESTIMATED V_R
CONSTRUCTION IN PROGRESS
342 m
112 m
1127 m
454 m
1805 m
ESTIMATED RUNWAY LENGTH OVERFLOWN
2,932 m
ESTIMATED AIRBORNE DISTANCE
1920 m
2195 m
ESTIMATED GROUND RUN
ESTIMATED GROUND RUN
ESTIMATED FLIGHT PATH
NAIROBI AIRPORT
GENERAL LAYOUT
SCALE — 1 : 10,000