SUMMARIES OF AIRCRAFT ACCIDENT REPORTS AS PREPARED BY ICAO

TAKE-OFF PHASE

No. 1

British United Airways, BAC 1-11, G-ASJJ, accident at S. Donato Milanese, Italy, on 14 January 1969. Report, not dated, released by the Directorate General of Civil Aviation, Italy. Translation of the report, issued by the Italian Commission of Inquiry, was published by the United Kingdom Board of Trade as C.A.P. 347

1.- Investigation

1.1 History of the flight

On 14 January 1969 the crew flew from Gatwick to Rotterdam and return, following which they departed on a scheduled international flight Gatwick-Genoa-Gatwick. For this flight Captain A occupied the left-hand seat as pilot-in-charge, Captain B the right hand seat as co-pilot and Captain C the centre supernumerary seat as pilot-in-command, ultimately responsible for the correct operation of the aircraft. Before leaving Gatwick Captain A briefed Captain B concerning the co-pilot duties assigned to him. Although Captain C, as pilot-in-command, did not himself formally brief Captains A and B there was no doubt that they were aware of their respective tasks.

On the flight from Gatwick to Genoa the aircraft was forced, due to unfavourable weather conditions at Genoa, to divert to Milan/Linate Airport where it landed at 1430 hours. Before commencing the return flight to Gatwick the crew had to await the arrival of the passengers from Genoa. This took place at 1930 hours.

During the five-hour waiting period on the ground, the aircraft APU was kept in operation to ensure cabin heating and air conditioning. While Captain C tried unsuccessfully to sleep in the aircraft, Captains A and B inspected the aircraft and found ice on the wings and tail unit. The aircraft was subsequently de-iced.

Before boarding the aircraft, Captains A and B made another external inspection of the aircraft and established that there was no ice on any part of it. The result of this inspection was duly reported to Captain C. Captains A and B carried out the pre-flight checks in accordance with the company check list and verified that the take-off weight and aircraft loading were within the permitted limits.

The crew occupied the same positions as during the previous flight, Captain A being in the left-hand seat, Captain B in the right-hand seat and Captain C in the jump-seat.

In view of the weather, temperature and runway conditions, the crew decided to use the 18° flap setting, Spey 2 thrust (full thrust), engine anti-icing and the APU for cabin air conditioning. V1 and Vr were established at 117 kt and V2 at 127 kt.

At 2018 hours, after clearance from Linate ATC, the engines were started and engine anti-icing selected "ON". There was a considerable layer of snow along the sides of the taxiways and runway, but they themselves were clear and usable. In view of the isolated patches of slush or water on the runway, Captain A considered it essential for the engine igniter switches to be selected "ON" during the entire take-off. At 2028 hours the aircraft was cleared to enter runway 18 and, after receiving the latest information concerning visibility and wind, it was cleared for take-off at 2031 hours.

Before the brakes were released, a check was made of engine P7 pressures and of the other engine instruments which were found to be normal. At about 80 kt Captain A took over the aircraft's control column. The air speed indicators showed regular acceleration and Captain A stated that just before 100 kt the engine instruments were also registering normally.

V1 and Vr were called and the aircraft was rotated into the initial climbing attitude; immediately after or during this manoeuvre, a dull noise was distinctly heard by all the crew members. This noise was variously described by them as: "not like a rifle shot, not like the slamming of a door or something falling in the aircraft but more like someone kicking the fuselage with very heavy boots, an expansive noise covering a very definite time span with a dull non-metallic thud".

The bang was immediately associated by the crew with the engines. After looking at the TGT gauges, and observing that No. 1 engine was indicating a temperature 20°C higher than that of No. 2 engine, Captain C said: "I think it's number one" or words to that effect, and after a brief pause "throttle it".

On receipt of Captain C's comment Captain A closed the power level of No. 1 engine. During or just after the explosion, he had completed the rotation manoeuvre and the aircraft was climbing at 12° of pitch with reference to the flight director. As a precaution, after closing No. 1 power lever he reduced the angle of climb to 6°. At the same time the co-pilot (Captain B) who had reached for the check list and was looking for the page relating to an engine emergency, became aware of a sharp reduction in the aircraft's acceleration; he noticed that the undercarriage was still down and he retracted it immediately.

According to the crew the aircraft reached a maximum height of 250 ft, after which a progressive loss of momentum became evident. A maximum speed of 140/145 kt was achieved immediately after rotation, but it fell to 127 kt after No. 1 engine had been throttled back. These figures were consistent with those subsequently derived from the flight recorder. The crew said that the stick-shaker operated three times between 125 and 115 kt. The co-pilot had a vague recollection that the stick-push and the warning klaxon operated during the critical phase before impact. The pilot-in-charge remembered vaguely that someone said "raise the flaps", but no crew member remembers doing so or making the retraction.

On looking out of the aircraft the crew saw the ground and the obstructions close at hand and realized that contact of the aircraft with the ground was inevitable and imminent. Captain A controlled the aircraft extremely well during the touchdown; the aircraft slid along the snow-covered surface, passing over small obstructions, and came to a halt 470 m from the point of first contact with the ground (see Fig. 1-1). The co-pilot operated both engine fire-extinguishers and Captain C ordered the pilots to leave the aircraft immediately via the side windows. During the ground slide an orange glow was seen to light up the glass panels of the windows for a short time. There was no fire.

After closing No. 1 power lever, Captain A remembered having ordered the shut-down drill for this engine but he could not say for certain whether this was done. It was established, however, that Captain B closed both the HP cocks at the first sensation of ground contact.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal			
Non-fatal		6	
None	7	20	

1.3 Damage to aircraft

The aircraft was substantially damaged during the ground slide. The whole of the lower fuselage was heavily damaged, especially the centre and rear sections of the fuselage where the lower structure and skin had been torn and lay in fragments along the path of the aircraft, as well as components of the air conditioning and hydraulic systems associated with these areas.

1.4 Other damage

There was no other damage.

1.5 Crew information

The pilot-in-command, Captain C, aged 46, held a valid airline transport pilot's licence with ratings in the Viscount and BAC 1-11 and an instrument rating. His last medical examination was on 24 October 1968. He was appointed Line-Check Captain for BUA on 1 January 1967 and always performed his duties as such satisfactorily. Although he had never experienced a real engine failure in a critical situation, he had been subjected to various simulated engine failures during training.

He had flown a total of 13 360 hours, including 2 153 hours in BAC 1-11 aircraft, of which 392 hours were flown in the last six months. He had flown 43 hours in the last 30 days and after three days off duty on 11, 12 and 13 January, he had been on duty for 14 hours at the time of the accident on 14 January 1969.

The pilot-in-charge, Captain A, aged 44, held a valid airline transport pilot's licence with ratings in the Auster V, Bristol 170, Skymaster, Carvair and BAC 1-11 aircraft and an instrument rating. His last medical examination was on 30 September 1968. He had experienced a real engine failure on take-off in a Skymaster C54 aircraft and his ability to deal with emergency situations in BAC 1-11 aircraft had been checked in a BAC 1-11 on 10 April 1968 and in a flight-simulator on 7 October 1968.

He had flown a total of 10 973 hours, including 497 hours in BAC 1-11 aircraft. He had flown 42 hours in the last 30 days and after being off duty on 13 January he had been on duty for 14 hours on the day of the accident.

The co-pilot, Captain B, aged 42, held a valid airline transport pilot's licence with ratings in Bristol 170, Britannia and BAC 1-11 aircraft and an instrument rating. His last medical examination was on 25 October 1968. He had flown a total of 12 135 hours, including 33 hours in BAC 1-11 aircraft. He had been off duty on 11 and 12 January and had been on duty 19 hours during the last 48 hours, including 14 hours on the day of the accident.

Also aboard was an ATC officer on a familiarization flight. He occupied the seat immediately behind the left hand pilot seat. There were four cabin attendants aboard the aircraft.

1.6 Aircraft information

The Certificate of Airworthiness of the aircraft was valid until 5 April 1969. The aircraft had been properly maintained in accordance with the provisions of the approved maintenance schedule; the most recent general inspection had been carried out on 29 November 1968.

Following inspection a Certificate of Maintenance had been issued which was valid for 90 days or 675 flying hours. The last check (Inspection Area Check 5) had been carried out on 11 January 1969. The aircraft had flown a total of 8 310 hours, of which 293 hours had been flown since the general inspection.

Engine No. 1 (Spey 506-14AW) had undergone a general overhaul by Rolls Royce in October 1967 following which it was released for a further 3 500 hours. It was then installed in position No. 1 on the subject aircraft and had run for 2 950 hours since then. It had been properly maintained.

Engine No. 2 (Spey 506-14AW) had been completely overhauled by Rolls Royce in March 1966 following which it was released for a further 3 500 hours. It was installed in the No. 2 position of the subject aircraft, but removed after 13 hours of operation and returned to the manufacturer for repair because of ingestion of foreign material. In May 1966, after repair, it was released and certificated for a life of 3 500 hours and reinstalled in the subject aircraft in No. 2 position where it operated until December 1967, completing a total of 4 980 hours since manufacture and 3 502 hours since the last complete overhaul. It was then removed from the aircraft and returned to the manufacturer with a suspected turbine blade failure. After partial overhaul it was released in April 1968 and certificated for a further 3 500 hours, i.e. a total approved life of 7 000 hours.

In May 1968 it was reinstalled in the No. 2 position of the subject aircraft where it ran until 26 November 1968, completing 5 058 hours operating time since its complete overhaul in March 1966. It was removed from the aircraft to allow replacement of the glass fibre fairings in the by-pass duct, which were found to be unserviceable following a report of vibration in flight.

New components were fitted and the engine was again reinstalled in the No. 2 position of the subject aircraft on 29 November 1968. The engine was found to operate normally during ground running and in flight. The vibration level was monitored with appropriate equipment by technical staff of the manufacturer and was found to be within the normal operating limits.

At the time of the accident the engine had run for 5 532 hours since complete overhaul, out of an approved operating life of 7 000 hours. Since its last installation in the aircraft it had run for 293 hours. During this time it had been maintained in accordance with the approved maintenance schedule of the operator.

The Certificate of Maintenance of this engine was valid. A check, reference NE Group Q, had been completed at Gatwick on 11 January 1969 and a Check "A" inspection at 0600 hours on 14 January 1969.

Inspection of the Technical Log sheets for the flight carried out during the last 293 hours of operation revealed two entries as follows:

3 December 1968

During Check "A", bird ingestion was found in No. 2 engine. The remains were cleaned out and the hot and cold ends inspected for damage; no damage was found. A ground run was carried out and the engine performance was satisfactory.

The performance of the engine was satisfactory during the subsequent 275 hours 31 minutes of operation.

7 January 1969

A hot start was noted. No rectification was considered necessary and the performance of the engine during subsequent starts was normal.

At the time of take-off from Linate the weight of the aircraft was 31 361 kg, including 6 973 kg of fuel. This was below the maximum authorized take-off weight of 35 833 kg, and the centre of gravity was within allowable limits.

1.7 Meteorological information

On the day of the accident the presence of a persistent area of low pressure over the Gulf of Genoa gave rise to thick layers of dense cloud, accompanied by rain and snow, over the whole of Northern Italy. Milan Linate Airport in particular had been closed to traffic until 0630 hours on 14 January, on account of snow clearance work on the runway during the night and regular SNOWTAM were issued throughout the day. The snowfall was followed by heavy rainfall which continued until an hour before take-off.

At the time of take-off the runway was completely clear of snow, but there were some isolated patches of slush; the visibility was fairly good and the wind light. The 2020 hours Linate weather report was in part:

Wind 240°/5 kt; Visibility 2.5 km; Clouds 3/8 St at 800 ft, 8/8 St at 2 000 ft. Temperature 1°C; Dew point 1°C, QNH 987.7 mm Hg.

1.8 Aids to navigation

Not relevant to this accident.

1.9 Communications

There were no communication difficulties between the ATS and the aircraft. No message regarding an emergency was sent by the aircraft.

1.10 Aerodrome and ground facilities

All installations at Linate were operating normally at the time of the accident.

1.11 Flight recorders

The aircraft was equipped with a Sperry Airborne Data Acquisition System flight data recorder, which recorded the following parameters: IAS, pressure altitude, magnetic heading, normal acceleration and pitch attitude, as a function of time. The recording was sent to the United Kingdom Board of Trade for read out.

Examination of the initial part of the flight showed that acceleration during the take-off run, up to rotation speed, was normal for a BAC 1-11 with 18^{o} flap and that there was no deficiency in thrust up to the time of rotation. The corrected data for speed and altitude were therefore used to plot the graph of the aircraft's total energy against time for the period from take-off until the end of the flight (see Fig. 1-2). The slope of this graph at any point is proportional to the excess of thrust over drag, so that the variation of engine thrust and of the aircraft configuration during the flight can be seen. For about 10-12 seconds after unstick, which occurred about 26 seconds after release of brakes, the thrust exceeded the drag and the energy increased. The energy reached a maximum at about 37 to 38 seconds from release of brakes and then decreased steadily, showing that the drag exceeded the thrust.

Analysis of the data between 40 seconds and 60 seconds indicated that there were no changes in thrust or configuration during this period: on the assumption that the undercarriage was retracted and one engine windmilling during this period, it was calculated that there was a residual thrust of 3 600 lb. Assuming that the undercarriage was still down, this figure would need to be increased by 700 lb. The undercarriage position cannot be deduced from the graph; the information relating to the aircraft's attitude confirmed that the flaps were still at 18 degrees during this phase. The graph of the total energy was subsequently corrected for the phase following the rotation manoeuvre, by altitude data obtained by twice integrating the values of normal acceleration (see Fig. 1-3). Near the ground, the altitude values obtained in this way were considered to be more reliable than those obtained from the barometric altitude transducers of the flight recorder (see Fig. 1-4). This second graph of the total energy showed a sharp change in slope at about 29 seconds, followed by a straight line, with very little scatter of the points up to 37 seconds. The conclusion is that there was a substantial reduction in thrust immediately after take-off and that it continued at this reduced level, without any noticeable recovery, during the next period up to 37 seconds.

The data for the first 60 seconds were consistent with an acceleration up to rotation speed with both engines at maximum thrust and a normal take-off, followed immediately by a rapid reduction of about 30 per cent in the total thrust. Then, at about 37 seconds from release of brakes, there was another reduction in thrust, compatible with the throttling back of No. 1 engine, and the undercarriage was retracted, after which the aircraft lost height and/or speed so that the total energy decreased during the remainder of that period of time.

1.12 Wreckage

The area where the aircraft landed consisted of flat open fields crossed by dirt roads and ditches. The roads and ditches were lined with trees, usually cut down at the base, with thin bushes and shoots breaking out of the tree trunks. At the time of the accident the ground in question was covered with snow and sodden by the heavy snowfall followed by persistent rain.

The aircraft touched down in a level attitude, with the undercarriage retracted and slid over the ground for a distance of 470 m, crossing two dirt roads and three ditches before coming to a halt, apparently intact as far as the general airframe structure was concerned. The condition of the wreckage and the length of the ground slide gave reason to think that the aircraft had a relatively low forward speed at the time of impact. There was no evidence to suggest that the aircraft had a high rate of sink. The impact with the ground, unnoticed by almost all the passengers, and the angle of descent calculated on the basis of the distance between the first point of impact and three trees broken by the aircraft at a height of 9 m above the ground, 300 m before that point, confirmed the hypothesis of a flight conducted at the stalling speed limit. The precise point of touchdown coincided with the end of a vegetable storage clamp, 50 m long, 3 m wide and 1.5 m high. The inboard section of the starboard wing grazed the clamp, losing two flap sections. Subsequently, No. 2 engine nacelle struck the clamp heavily and in consequence separated from the fuselage during the first part of the ground slide and came to rest 300 m from the point of touchdown. The thrust reverser unit and the tail pipe, on the other hand, came to rest 200 m from the point of touchdown.

The ground slide was clearly shown by a continuous mark on the ground from the point of touchdown, except for a distance of about 15 m where the aircraft bounced on crossing a drop in field level. While crossing the obstructions constituted by the dirt roads and banks the aircraft sustained damage to the underside of the fuselage and the flap unit became separated from the aircraft as a result of impact with a large tree stump which penetrated the wheel bay. The wheel was carried away, displacing the left half of frame 620 bulkhead and during its displacement it passed under the floor of the rear of the passenger cabin, causing damage in the seating area and injuries to a passenger.

The leading edges and flap sections of the wings were damaged as a result of impacts with trees. It was concluded that at the time of impact the flap selector lever was at a position between the retracted position and the position corresponding to 8 degrees. The flaps were in the process of retraction and had reached a position corresponding to 13 inches of extension with an angular displacement of less than 3 degrees.

The spoiler/airbrakes were undamaged and were in the retracted position during the ground slide.

1.13 Medical and pathological information

In an attempt to explain why Captain C had made such a hasty decision concerning the apparent engine failure, he agreed to undergo a thorough examination by medical specialists. The examination, however, did not reveal any valid psychological explanation.

1.14 Fire

No evidence of fire was found in any part of the wreckage or in the area traversed by the aircraft during the ground slide.

The crew operated the aircraft fire extinguisher system after impact.

1.15 Survival aspects

The floor of the passenger cabin was damaged at the left rear aft of frame 590 where the floor beams had been disrupted and the floor pushed upwards, displacing the fifth and sixth pair of seats from the rear. However, these seats remained attached to their rails and were not damaged.

After the evacuation of the aircraft, conducted in an exemplary manner by the crew and the cabin attendants, the occupants waited for about an hour for the arrival of rescue teams. This was attributed to the fact that although the latter were alerted immediately, the location of the wreckage was difficult to find not only because of the particular area but also because the night was wet. No person living in the area noticed anything unusual and no emergency message was sent by the crew.

1.16 Tests and research

1.16.1 General

Both engines were sent to Rolls Royce for examination.

Nothing was found in No. 1 engine to indicate that the engine was not in a condition to develop its normal performance before impact. During the bench test a small piece of metal was ejected from the engine and minor damage to the high pressure compressor was found. Spectographic analysis of the metal indicated that it was not part of the engine and it was concluded that it was part of the airframe structure ingested by the engine during the ground slide.

Examination of No. 2 engine revealed some damage, apart from that caused by ingestion of foreign material during the ground slide, which could have affected the engine performance and behaviour. Further investigation of these parts revealed the following:

All sixteen HP 1 and HP 2 turbine dowel bolts had failed in fatigue at the nut ends and the latter were jammed under the connecting flange. The bolts in question were of early modification standard and were known to fail in this way. In the past, many engines had been found in a similar condition during overhaul. Although not a very desirable feature, this failure cannot be connected with any loss of engine power.

The two fibre-glass fairings in the by-pass duct immediately to the rear of the bleed valves were in poor condition, over-heated and severely delaminated. This defect is relatively common to Spey engines and could not have affected the engine's performance.

Finally, the only other damage found was to one of the 16 HP 2 turbine labyrinth seal segments which had become displaced from its slot and had fouled the HP 2 turbine sealing ring. There have been only three previous instances of this defect and in two of the three cases the defect caused a bang, which was heard in the aircraft, and sparks from the tail which were seen from the ground. The previous cases occurred during ground running and the engines were immediately shut down; it was therefore not known what would have happened if the throttles were left open.

Preliminary calculations carried out by the Rolls Royce engine design and performance engineers indicated that the only effect should have been a momentary compressor stall and a small loss of HP 2 turbine efficiency (from 1 per cent to a maximum of 3 per cent) and that within a few seconds the engine should have recovered thrust almost equal to the take-off thrust. Further tests were carried out by Rolls Royce in order to study the engine's behaviour after damage of this kind. Metallurgical tests and detailed examination of the turbine section revealed no evidence of excessive temperature such as would result from overfuelling in the case of sustained or prolonged compression stall.

The fuel system of the engine was also bench tested and it was found to be normal and within the specified limits. Fuel samples taken from the engine filters by Rolls Royce engineers were examined in the laboratory. The samples were found to conform to specifications and to be uncontaminated.

1.16.2 No. 2 engine

Tests demonstrated that damage to the HP turbine seal would result in an insignificant decrease in thrust, an increase of 18°C in TGT and a negligible increase in fuel consumption.

During the tests the failure of the HP seal was simulated by the use of an engine adapted for the purpose by the transfer of the turbine blades of the engine of G-ASJJ to an appropriate turbine disc. The detached seal segment, which in the case of the engine under investigation had finally lodged against the next set of nozzle guide vanes, could not be reproduced and the simulation could be achieved only by removing a seal segment. After its appropriate calibration was checked the combined acceleration and speed control unit of No. 2 engine was fitted to the test engine.

Initially the tests were carried out without the amplifier and the fuel dip control. The condition of the engine on the test bed, therefore, although representative of No. 2 engine running in a steady state, could not provide a simulation of the dynamic conditions existing at the moment of displacement of the seal. While running under these conditions the engine showed no tendency to surge, even during violent accelerations; it behaved normally although with a slight deterioration in efficiency.

Rolls Royce considered that the bang/surge occurred as a result of the displacement of the seal segment and not vice versa; for obvious reasons of installation these conditions could not be reproduced on the test bed. This hypothesis is, however, borne out by the two previous cases of seal segment detachment which occurred on the ground; both cases were discovered after surging and a shower of sparks from the turbine. After the performance of the test engine had been established, a series of simulated take-offs was carried out and there was no surging.

The fuel consumed during the various stages was recorded and compared with the consumption during the period between engine start-up and the impact, on the basis of the indications of the aircraft kilogrammes-gone gauges. The figure obtained was consistent with that for No. 2 engine, with power reduced after 27 seconds to an equivalent rpm for 3 750 lb of indicated thrust. At 37 seconds the consumption recorded, when No. 1 engine had been throttled back, was consistent with 122 kg in three separate tests. This gave reason to believe that No. 1 engine fuel might have been cut off at this point as opposed to the supposition that it operated at flight idle for a further 51 seconds. In fact, with a consumption of 7.5 kg per minute, the consumption at the time of the impact would have had to be 128 kg on No. 1 gauge.

The fuel consumed during the whole run of 14 minutes 35 seconds, without shutting down, was 175 kg and this figure is appreciably higher than that for the consumption of No. 2 engine during the same time (155 kg).

On throttling the test engine to 3 750 lb of thrust at 13 minutes 27 seconds and maintaining this condition for the remainder of the run, the fuel consumed was 140 kg. This suggested that the figure of 3 750 lb of thrust, arrived at by the original energy calculations, was approximately correct and consistent with the fuel consumed, with allowance for the fact that No. 2 engine was the first to be started and its consumption would therefore have accounted for the difference between 140 and 155 kilogrammes during the longer period for which it was running. In addition, there would have been a further small increase in the effective thrust: the net thrust of 3 750 lb has been calculated by Rolls Royce to be equivalent to about 4 150 lb of gross or 86.2 per cent HP rpm.

In the light of the above, there was reason to think that both thrust and fuel consumption of No. 2 engine of G-ASJJ were reduced by commensurate values for some reason after the bang/surge.

During the next series of test runs, compressor surging was artificially induced by blanking the mixer unit downstream of the LP and HP compressors; an LP bleed was used to restore the previous situation.

When it was established that surging occurred after the blanking of the mixer unit, the LP air was bled away to allow the engine to accelerate to maximum rpm and in this way surging could be induced at will. During the first tests, however, as surging continued in an uncontrolled violent manner after the LP bleed was re-opened, the engine was shut down to avoid damage. This surging was violent and continuous, with repeated bangs, flashes from the air intakes and tail pipe and sparks from the tail pipe. These sparks were incandescent particles of dislodged carbon deposits. During the surging the engine showed no tendency to run down or maintain a state of reduced thrust but attempted to regain a full thrust state, accelerating between each surge.

The surges were phenomena of short duration, about 1/10th second, and separated by intervals of approximately 1.5 seconds; during the surges the thrust levels recorded dropped by 60 per cent and then recovered. The power level showed no tendency to kick back.

Since No. 2 engine of G-ASJJ had not been subjected to repeated surges of the magnitude and number observed during the tests - for they would certainly have been noticed and heard by the occupants of the aircraft - it was concluded that only one bang/surge occurred in the aircraft at the time of take-off and that this was a transitory condition as was the condition which caused it. It is also clear that the loss of power following the surge was probably caused by a reduction in fuel flow for some reason or other, but high speed recording of the parameters during the test surges did not reveal any tendency of the fuel flow or its controlling devices to remain depressed.

As a probable area of further examination, it was thought desirable to repeat the surge condition with the amplifier and fuel dip circuit installed in order to establish whether there was any spurious or transitory condition caused by some physical effect or unusual electrical effects of the surging on the amplifier, the amplifier circuit or the fuel dip solenoid. At maximum thrust, operation of the top temperature control and fuel dipping had little effect on thrust and rpm; there was, initially, a small reduction in rpm which was restored by the action of the governor. Sustained operation of the fuel dip resulted in a loss of about 8.2 per cent in the test condition with blanks fitted; when related to a maximum thrust condition without blanks and with engine anti-icing selected, the loss of thrust would have been 9 per cent in the mid-rpm range. When the fuel dip solenoid was continuously energized, its effect during induced compressor surges amounted to a loss of thrust of 400 lb or 3.8 per cent and there was no tendency for rpm and thrust to be depressed to a constant level beyond the brief transitory condition which occurred during the surge. This, together with the fact that the amplifier was attached to the engine mounting frame in the test bed and therefore subjected to considerable shock due to engine movement during the surging, and the fact that the fuel dip solenoid was deliberately energized throughout the induced surges, gave reason to conclude that the loss of thrust and throttling effect evident in No. 2 engine did not result from a malfunction of the amplifier and fuel dipper, before, during or after the bang/surge.

There remained only one further area of exploration. It was not known for certain what would happen if the HP cock was partly closed. This situation was first investigated by placing the HP cock lever in the "cold start" position while the engine was at full throttle; this had little noticeable effect on rpm and thrust, but further movement of the cock towards the closed position resulted in reduced thrust and rpm.

It was possible to reduce the thrust to about 300 lb before the engine would stop; but at least 3 750 lb would have been maintained before engine flame-out occurred. It was then decided to examine the effect with the LP characteristics restored to normal by removing the blanks from the mixer unit.

As the HP cock of No. 2 engine had already been removed, it was not possible to establish the exact angle of the cold start setting of the cock lever. Nevertheless, the cock and power lever linkage were re-rigged and set at an accurately calculated angle.

Further tests were carried out with the test engine restored to normal performance level (except for the defective turbine sealing) and it was found that the rpm and thrust could be reduced to below ground idle values by closing the HP cock beyond the cold start position. Engine performance was also checked at a number of positions, the rpm condition being set up by means of the HP cock instead of the throttle lever.

From these tests it was concluded that the thrust reduction of No. 2 engine could have resulted only from partial closure of the power lever or the HP cock. It was also concluded that the residual thrust, determined by total energy calculations, did not represent any particular or distinct engine condition caused by the detachment of the HP turbine seal segment and the resultant bang/surge or by any fuel control malfunction acting independently or in concert with the foregoing. The residual thrust was probably a random value resulting from a movement of the power lever or the HP cock or the incomplete closure of the latter.

2.- Analysis and Conclusions

2.1 Analysis

The events which contributed to the accident may be summarized in the following order:

(1) the compressor bang/surge of No. 2 engine;

(2) the intervention of Captain C, the pilot-in-command, seated in front of the instruments but not at the aircraft's controls;

(3) the erroneous diagnosis of a malfunction of No. 1 engine;

(4) the prompt execution of an "order" by Captain A, pilot-in-charge;

(5) the fact that the crew did not recognize their mistakes and take timely remedial measures.

The technical inspection of No. 1 engine revealed no defects, but inspection and testing of No. 2 engine showed that a segment of the HP turbine seal had become detached and had fouled the turbine blades. This fouling caused the stream of sparks clearly seen by eyewitnesses. The technical examination and testing established that the displacement of the seal segment caused a surge in the low pressure compressor which was clearly heard by the aircraft's occupants as a dull explosion. The surge was of very short duration and any decrease in thrust would have returned to at least 97 per cent of the original power within 1/10 second. Unless the crew members had been looking at the engine instruments precisely at the time of the bang, it is highly improbable that they could have seen any fluctuation in the indications of these instruments. The instrument measuring turbine gas temperature (TGT) of No. 2 engine would have indicated an increase of 10°C, equivalent to approximately one of the four marks between each "hundreds" mark on the graduated scale.

Apart from the established minor defect, No. 2 engine did not sustain any further damage up to the time of impact.

Extensive tests did not reveal any mechanical defects or malfunction of the fuel system which might have accounted for a considerable and sustained decrease in thrust. An analysis of the tests carried out and an accurate and detailed examination of the fuel consumed during the test programme lead to the conclusion that the loss of thrust revealed by the data obtained from the flight recorder, over and above that caused by the deliberate throttling down of No. 1 engine, might have been caused by a reduction in the flow of fuel to No. 2 engine within 10 seconds of the bang/surge.

The foregoing considerations are reinforced by the knowledge that the residual thrust before impact, as indicated by the calculations of the total energy on the basis of data from the flight recorder, was consistent with the quantity of fuel consumed after the engines were started and this can be associated only with an intermediate position of the throttle lever of No. 2 engine, a position corresponding to about 86 per cent HP rpm on the engine instrument. A more likely reason for this subsequent reduction in thrust could have been the inadvertent displacement of the throttle lever of No. 2 engine when No. 1 throttle lever was pulled back, or its inadvertent displacement in some other way which cannot be established. On the other hand, the total energy calculations reveal two discrete reductions in thrust, the first of which, equivalent to about 30 per cent of the total thrust, occurred about 3 seconds after the aircraft left the ground.

The effects of this reduction were greater and more prolonged than would be the case if the bang/surge were the sole reason.

This, therefore, suggests that the thrust of both engines may have been effectively reduced by means of a limited and precautionary pull-back of both power levers by a crew member shortly after the bang. The crew, however, had no recollection that this was done.

The real way in which the power lever of No. 2 engine was moved is probably less important than the events which subsequently occurred. After the intervention of the pilot-in-command and the subsequent throttling back of No. 1 engine, the crew had no reason to suspect a defect in No. 2 engine as well and in these circumstances the partial throttling of No. 2 engine passed unnoticed. The crew's attention would have been diverted from the engine instruments by the sudden operation of the stall warning round about 125 kt, 30 seconds before impact with the ground.

The crew's failure to recognize their errors, which should logically have been followed by the restoration of the engines to full thrust, made the emergency landing inevitable 64 seconds after take-off from Milan/Linate Airport.

Up to the time of the bang/surge, the pilot-in-command (Captain C) had played a completely passive role. The bang, distinctly heard by the crew, was immediately associated by them with an engine failure so that they were, so to speak, "preconditioned". When Captain C looked at the engine instruments he did not notice anything abnormal except that, in his opinion, the TGT of No. 1 engine was indicating a temperature 20°C higher that that of No. 2. This convinced him that No. 1 engine was malfunctioning and he said so to the crew. When the co-pilot heard Captain C say: "I think it's number 1" and a few seconds later: "throttle it", he had the impression that these remarks were addressed to Captain A in a conversational tone and not as a direct and precise order. Captain A, however, interpreted these remarks as a direct order from the pilot-in-command. Although Captain C was not suffering from exhaustion, his fatigue could have affected his powers of analysis, thereby contributing to his hasty and erroneous diagnosis of an engine malfunction, which, in turn, initiated an inopportune, incorrect and wholly prejudicial course of action.

The Company's instructions stated that in the case of an engine malfunction on take-off, not accompanied by fire, nothing should be done by the pilot-in-charge or the co-pilot before a safe height is reached.

The Company's Training Manual did not specifically define any safe height, because of the various climatic and topographical conditions under which an aircraft is operated; but each pilot was instructed during training to:

- reach V2 before retracting the undercarriage

- reach a safe height before beginning the appropriate emergency drill.

This safe height had been assessed to be about 700 ft for the weather and topographical conditions at Milan/Linate at the time of take-off.

Captain A, in answer to a question as to what his reactions would have been if the pilot-in-command had not been present, stated that he would have left everything until a safe height of at least 700 ft had been reached; the co-pilot should be then have positively identified the failure. It was therefore believed that his erroneous reactions were due in no small measure to the presence of the pilot-in-command in the jump seat.

In connexion with this aspect it should be noted that Captain C stated:

"It is perhaps not quite correct to be ultimately responsible for the safe handling of an aircraft in an emergency unless occupying a seat from where this can be done. I feel, somehow, that had I been occupying either of the pilot's seats I might have reacted differently; on the other hand, it is possible that had I not been present the two pilots might also have reacted differently."

Examination of the United Kingdom legislation revealed that at the time, the pilot-in-command had the right not to occupy either of the pilot's seats during the take-off and landing phases.

In the case under consideration, the presence of a suitably qualified Captain was regarded as necessary in order to supervise the co-pilot who, although a Captain and competent to operate the aircraft, was still a trainee in the eyes of the Company. In the light of this accident, the desirability or need for a supervisory Captain to exercise over-all command from the jump-seat, in those cases where the pilot-in-charge in the left-hand seat is a capable, experienced line Captain, might be considered worthy of re-appraisal by the competent authorities. The presence of a pilot of a superior grade on the flight deck tends to disrupt the even tenor of the activities of the crew, placing the latter in a state of subjection, and there have been cases of previous accidents which were attributed to precipitate and incorrect action by the pilot-in-command who was occupying the jump-seat.

Notwithstanding the foregoing considerations, the crew of G-ASJJ and the seats they occupied in the aircraft were not in conflict with Article 28 of the United Kingdom Air Navigation Order, 1966, which stipulates that two properly licensed pilots must be at the controls of the aircraft during both take-off and landing. Captains A and B were properly licensed.

2.2 Conclusions

(a) Findings

BAC One-Eleven G-ASJJ was fully airworthy at the time of its clearance for take-off from Linate; it had been properly maintained and was correctly loaded.

The crew members were correctly licensed and the crew positions they occupied on the flight deck and the duties entrusted to them were in accordance with the company's rules and United Kingdom regulations.

A segment of the HP turbine seal of No. 2 engine caused a compressor bang/surge which led the crew to think that there was a serious engine malfunction. The loss of thrust attributable to this defect was negligible.

Tests have shown that there were no defects or failures of the engine fuel system or fuel controls which could be associated with the loss of thrust over and above that resulting from the deliberate throttling of No. 1 engine.

No. 1 engine was throttled back after an erroneous order or piece of advice and its throttle lever was pulled rearwards rapidly.

The major loss of thrust in No. 2 engine was probably due to the displacement of the throttle lever by a crew member and to the fact that its partially open position remained unnoticed during the period of confusion preceding the emergency landing.

The incorrect diagnosis of a malfunction of No. 1 engine after the bang/surge can be attributed to the hasty intervention of the pilot-in-command and this could be attributed to fatigue, aggravated by the long duty period.

In rapidly throttling back No. 1 engine, the pilot-in-charge promptly executed without question what he thought to be an order instead of waiting until a greater height was reached and then taking any appropriate action.

The judgement and actions of the pilot-in-charge were influenced by the presence of an experienced pilot designated as pilot-in-command, although the latter's specific task was the supervision of the co-pilot.

If the aircraft pilot-in-command had been seated at the controls, he might have acted correctly; similarly, if he had been responsible solely for the supervision of the co-pilot and had not been designated as pilot-in-command, the pilot-in-charge would have had a wider and more responsible field of action and would very probably have complied with the company's prescribed drills.

(b) Cause or
Probable cause(s)

The accident must be attributed to a combination of factors following a compressor bang/surge in No. 2 engine immediately after take-off and the aircraft crashed because the crew, after fully closing No. 1 throttle in error, failed to recognize their mistake and, in addition, were not aware that the thrust of No. 2 engine had also been partially reduced after an inadvertent displacement of the relevant throttle lever.

3.- Recommendations

(a) The intervention of the commander, or check pilot, supernumerary to the normal crew at the controls, appears to have been a distracting factor to the pilots in the correct performance of their duties. A state of subjection resulting from the presence of a pilot with supervisory duties seems to have constrained the crew at the controls, and in particular the pilot-in-charge, to accept orders or advice, without any contribution on their part of the competency of which they were certainly capable, for a calm identification of the causes of the bang which they had heard and for the application of the appropriate company drills.

Attention is therefore drawn to the advisability of reconsidering the position of a supernumerary pilot and his tasks and responsibilities, with particular reference to the question of whether or not it is desirable for the aircraft commander to be seated at one set of the controls.

(b) The accident to G-ASJJ once again raises the question of erroneous corrective action taken by pilots immediately after an emergency has arisen; such action is almost always prompted by equivocal reading of the aircraft's instruments, particularly when the reading and subsequent interpretation is made under stress. Although in the case of G-ASJJ there is scant evidence to support a conclusion that engine instrument presentation misled the commander, it is thought that some indication that a temporary fault had occurred in No. 2 engine might have been of assistance to the crew and decreased the possibility of an erroneous assessment, particularly under conditions such as those which obtained when the bang/surge occurred. It is, therefore, recommended that every effort should be made to lessen the possibility of aircraft accidents occurring due to erroneous interpretation of the readings of aircraft instruments which, although seemingly rational and functional in design, still mislead reliable and experienced pilots.

(c) The accident shows to what extent the human factor has a decisive effect on the sequence of events. The tragic experience of the past has provided ample evidence that it is not enough to establish adequate emergency procedures in order to cover the widest range of technical contingencies.

When confronted with unexpected and difficult flight conditions, human weakness tends to prevail over the reasoning powers of experienced men, suddenly and dramatically faced with mortal danger.

It is, therefore, recommended that all suitable means be adopted to enable pilots to obtain an adequate knowledge of human factors which, as much experience has already shown, will be conditioned by the particular environment in which they operate.

ICAO Ref: AIG/008/69

B.A.C. ONE-ELEVEN G-ASJJ AT LINATE AIRPORT - 14th JANUARY 1969

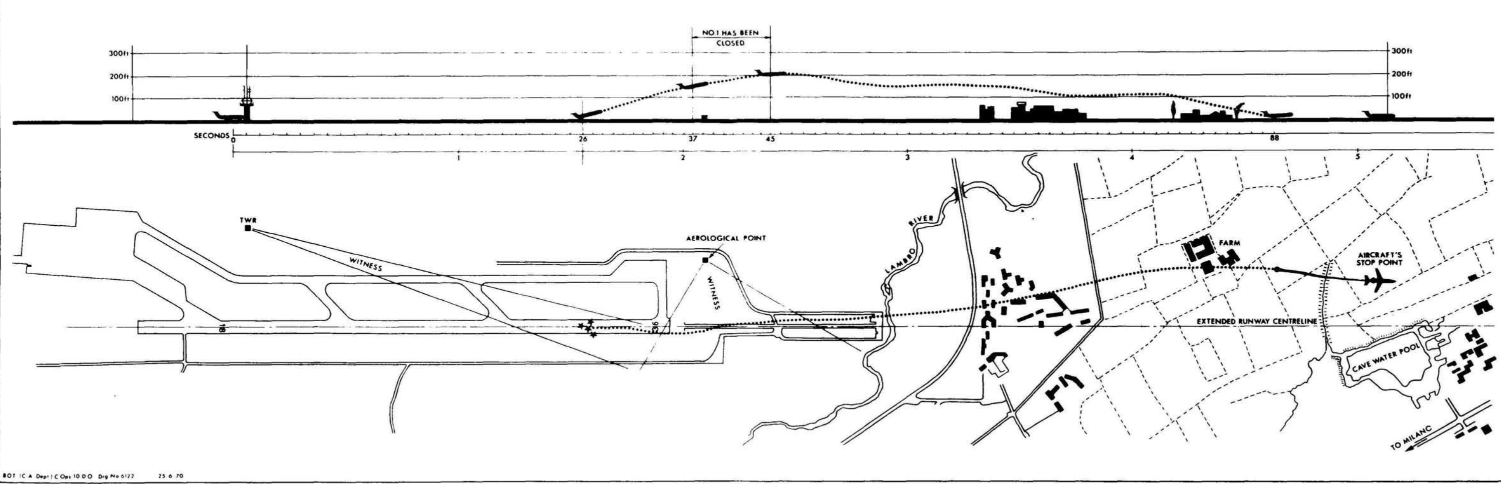

Figure 1-1

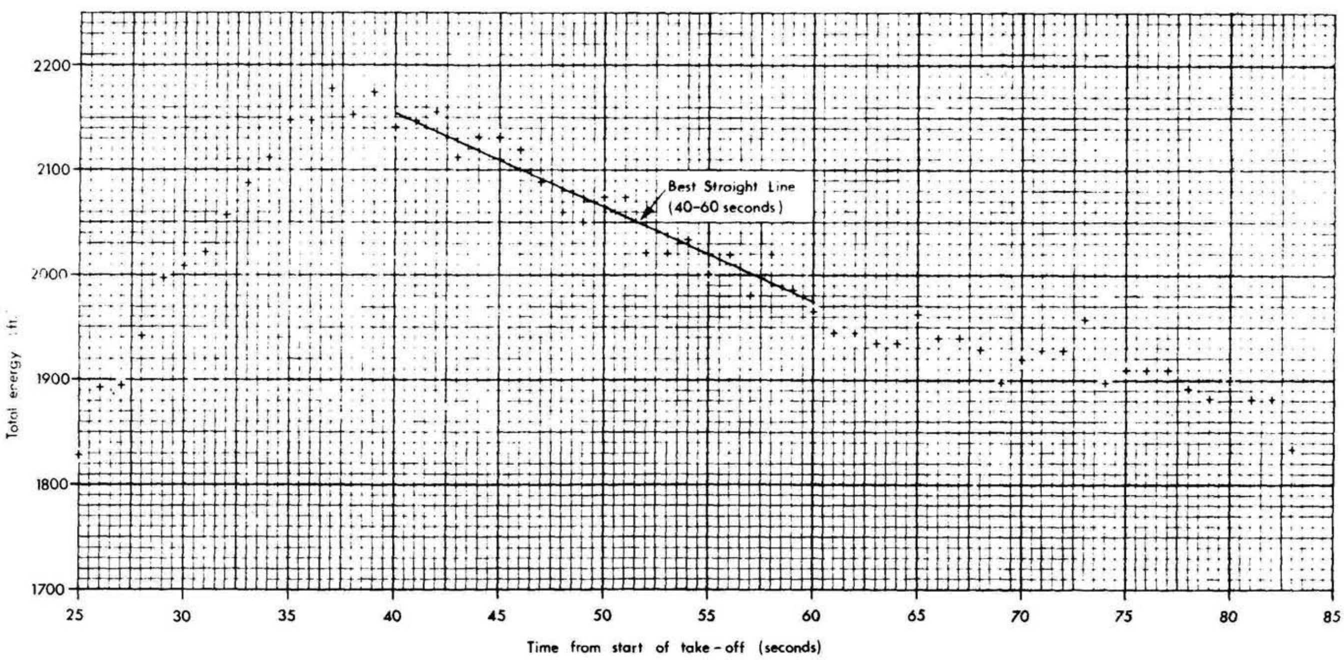

Figure 1-2.- Variation of Total Energy with Time, from Unstick to the End of Flight

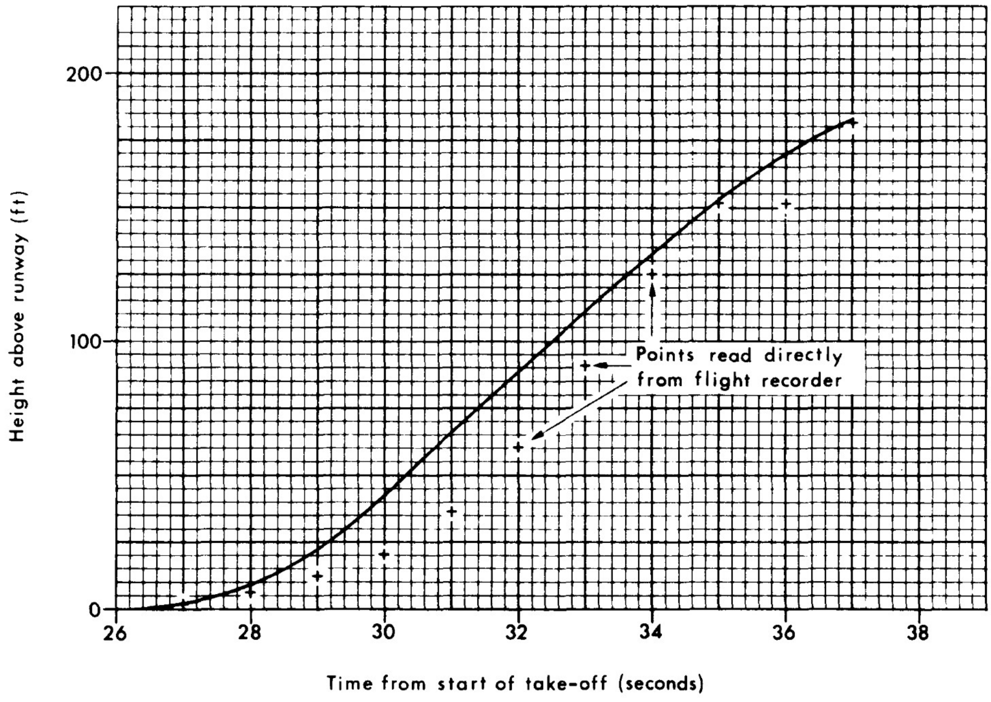

Figure 1-3.- Comparison of Height Trace Obtained by Integrating the Acceleration Information with that Obtained directly from the Recorder

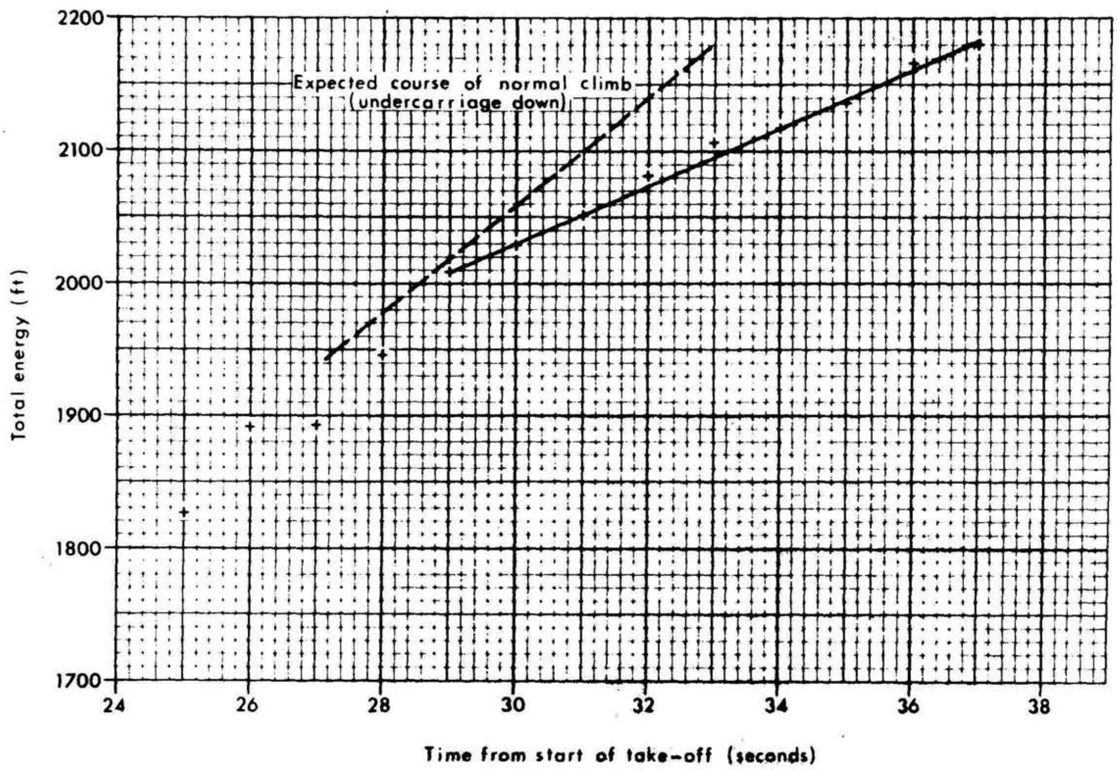

Figure 1-4.- Total Energy Curve for period immediately after Take-off, using Integrated Height Data