No. 11

British European Airways, Vanguard, G-APEE, accident at London (Heathrow) on 27 October 1965. Report, undated, released by the Board of Trade, United Kingdom, C.A.P. 270

1.- Investigation

1.1 History of the flight

The aircraft was on a scheduled domestic flight from Turnhouse Airport, Edinburgh to Heathrow Airport, London. The flight departed Turnhouse at 2317 hours GMT on 26 October and was uneventful until Garston VOR, the holding point. At 0015 hours the pilot-in-command decided to attempt a landing on 28R. The co-pilot was probably making the ILS approach, monitored on PAR by the air traffic control officer, while the pilot-in-command would be seeking a visual reference to enable him if possible to take over control and land. RVR on this runway was reported as 350 m. At 0023 hours the pilot-in-command informed ATC that he was overshooting. He then decided to make a second attempt, this time on 28L for which the RVR was reported as 500 m. Since the ILS was operating on glide path only and not in azimuth, ATC provided a full talkdown. At half a mile from touchdown the PAR Controller was not entirely satisfied with the positioning of the aircraft in azimuth and was about to give instructions to overshoot when he observed that the pilot had in fact instituted overshoot procedure. At 0035 hours the pilot-in-command reported that they overshot - because they did not see anything. He then requested to join one of the stacks and hold for a little while. This request was granted and the necessary instructions given. The pilot-in-command decided to wait for half an hour. The aircraft then circled at the Garston holding point. At 0046 hours another Vanguard landed successfully on 28R and the subject flight was informed of this at 0052 hours. At 0111 hours, although there had been no improvement in the weather conditions, the pilot-in-command probably stimulated by the other aircraft's success, asked permission to make another attempt to land on 28R. Meanwhile another Vanguard aircraft had overshot on 28R and the pilot-in-command of Double Echo was told by the pilot-in-command of this aircraft that he had not seen a thing from 200 ft on that attempt. However, Double Echo started another monitored ILS final approach on 28R at 0118 hours. At 0122 hours the PAR controller passed the information that the aircraft was $\frac{3}{4}$ of a mile from touchdown and on the centre line; 22 seconds later the pilot-in-command reported they were overshooting. The PAR Controller continued to watch the radar trace on his screen, saw the aircraft apparently climb away to about 400 - 450 ft and then the climb changed to a steep dive ending on the runway. The aircraft hit the runway about 2 600 ft from the threshold. The accident occurred at 0123 hours.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	6	30	
Non-fatal			
None			

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

There was no other damage.

1.5 Crew information

The pilot-in-command, aged 43, held a valid airline transport pilot's licence endorsed for command on Vanguard aircraft including an instrument rating. He joined BEA in 1947 and in 1952 he completed the Command Course and subsequently flew as pilot-in-command on Viking, Pionair, Viscount and Vanguard aircraft having completed his Vanguard conversion course in January 1964. He had flown a total of nearly 12 000 hours, including 1 049 hours on Vanguards. He had flown 40 hours during the 28 days prior to the accident. He was occupying the left-hand seat on departure from Turnhouse.

There were two co-pilots aboard the flight. The first co-pilot, aged 26, had obtained a commercial pilot's licence in October 1963 and a senior commercial pilot's licence endorsed for co-pilot on Vanguard aircraft and including an instrument rating in May 1965. His licence was valid and he was qualified to act as co-pilot on the subject flight. He had flown a total of 1 381 hours including 1 155 hours as co-pilot on Vanguards. He had flown 61 hours during the 28 days prior to the accident. He was occupying the right-hand seat on departure from Turnhouse.

The second co-pilot, aged 34, had obtained a commercial pilot's licence in 1957 and an airline transport pilot's licence endorsed as co-pilot on Vanguard aircraft and including an instrument rating in May 1964. His licence was valid and he was qualified to act as co-pilot on the subject flight. He had flown a total of 4 450 hours including 2 066 hours as co-pilot on Vanguards. He had flown 53 hours during the 28 days prior to the accident.

The flight, duty and rest times of the three pilots were all in compliance with the statutory regulations. However, the pilot-in-command and the first co-pilot were on their second consecutive terms of night duty; meteorological conditions were bad; two attempts to land, inevitably involving strain, had already been made and 40 minutes had elapsed between the previous attempt and the time of the accident. Therefore there is little doubt that some degree of fatigue played a role in the accident.

Also aboard the flight were two stewardesses and a steward.

1.6 Aircraft information

The aircraft's certificate of airworthiness was valid until 1 December 1965. The aircraft had been properly maintained and its certificate of maintenance was valid. Although the flight time was estimated to 65 minutes, sufficient fuel for 6 hours was on board. The weight of the aircraft and the position of the centre of gravity were within allowable limits. The type of fuel being used was not stated in the report.

1.7 Meteorological information

The meteorological reports given to the pilot-in-command before departure forecast fog, visibility of 100 m and runway visual range of 400 m at Heathrow. Weather reports were passed to the aircraft in flight regularly, showing little change in visibility at Heathrow.

1.8 Aids to navigation

Full instrument landing system (ILS) was available on runway 28R, whereas only the ILS glide path was available on 28L. Precision Approach Radar (PAR) was available on both.

1.9 Communications

The PAR controller was in contact with the pilot-in-command until the time of the accident and no communications difficulties were encountered.

1.10 Aerodrome and ground facilities

No information regarding the approach and runway lighting was contained in the report. RVR lights were installed along runway 28R but they had not been calibrated for a considerable time and therefore were giving an erroneous figure, approximately 50 m too high.

1.11 Flight recorders

The aircraft was fitted with a Plessey-Daval flight data recorder recording every 1/20th of a second the time interval, every 1/5th of a second the pitch attitude and the normal acceleration and every second the indicated altitude, the indicated airspeed and the magnetic heading. Although the impact and ensuing fire were extremely severe the recording was recovered intact. The recorder did not work entirely satisfactorily during the first two approaches and overshoots on the night in question, but before the third approach the fault had righted itself, and records were therefore available of the whole of the flight path from the beginning of the approach up to the moment of impact.

The composite picture presented by the direct recordings of the FDR and the further calculations made from them is illustrated by Figure 11-1.

From this it will be seen that at -20 seconds the aircraft was about 50 ft lower than the height recorded, and the co-pilot's altimeter probably indicated about 250 ft. The true height was about 190 ft.

At -18 seconds the aircraft was coarsely rotated upwards. The pitch-attitude was changed from 6° nose down to about 8° nose-up. This was the initiation of the overshoot.

The engine power was increased to full throttle at about -19 seconds. Some 5 seconds would be required to achieve full power.

The changes of heading* at this stage were due to the gyroscopic forces of the propellers and engines together.

*Not shown on Figure 11-1.

Flap retraction was commenced between -15 and -12 seconds; undercarriage retraction one or two seconds after this.

At -15 seconds there was a partial change of attitude towards the horizontal, followed by a further significant upward movement of the elevators at -12 seconds.

At -10 seconds there was a relaxation of the backward pull on the elevators followed by a progressive downward movement of the elevator control.

At -9 ½ seconds, as we know from the transcript of the R/T conversations, the pilot-in-command announced that the aircraft was overshooting. This message ended at -8 seconds.

At this moment the flaps had started to retract beyond the 20° mark and the flap indicator dial would accordingly be showing the abnormality. The air speed indicator was showing a steady 135 kt, the vertical speed indicator was indicating a climb of 1 200 ft/min.

Thus all these instruments were indicating to the co-pilot the necessity of easing off his rate of climb, and this is what he did.

A slow build-up of speed then took place, so that at -4 seconds the indicated air speed was 152 kt.

But the altimeter was still at that stage showing an increase in height, reaching its maximum (at -4 seconds) of 440 ft and the vertical speed indicator at that point was still showing a 1 200 ft/min climb.

The control column was still held or trimmed forward.

At -3 seconds the vertical speed indicator was still showing a climb of 600 ft/min, although the aircraft had been descending for 2 ½ seconds and the control column had been forward of neutral for 4 seconds.

At -1 ½ seconds a violent pull-up was initiated.

1.12 Wreckage

No information was contained in the report.

1.13 Fire

The impact on the runway and the ensuing fire were both extremely severe.

1.14 Survival aspects

Despite the fog, the airport fire fighting equipment arrived at the scene of the accident within two minutes. Everyone on board the aircraft had been killed on impact.

1.15 Tests and research

At the time of the accident the material part of the overshoot procedure was:

1. Application of power

2. Rotation of aircraft upwards

3. Retraction of flaps to 20°

4. Retraction of undercarriage.

It was not until 14 October 1965, after two incidents, one on 6 October and the other on 14 October, had been reported by the pilots, that the overshoot procedure was queried. The common features of these two incidents were:

(i) each happened during an overshoot in conditions of bad visibility, following an ILS approach;

(ii) in each case the co-pilot was meeting a situation he had not had to face "in anger" before;

(iii) in each case there was an erroneous interpretation of aircraft pitch attitude and/or build-up of speed;

(iv) each case involved an incorrect forward pressure on the control column, which resulted in a great loss of height;

(v) in each case there had been no reason to suspect the competence of the co-pilot to fly safely and correctly on instruments.

On 27 October 1965, the day of the accident, the following, a revised overshoot procedure was promulgated for the Vanguard:

1. Apply full power. Check speed.

2. Establish the aircraft in the climb at the correct speed.
SFS Radio OFF (Stn. 3).

3. When climb established: Flaps to Take-Off, Check.

4. Undercarriage UP. Lights out.

5. Engine instruments. Check.

6. Port ALT as required. Starboard to QNH.

7. Normal after take-off drills to be completed.

On 16 and 17 March 1966, a series of test flights was made at Bedford in another Vanguard (Echo Delta) in order to throw light, if possible, on Double Echo's accident. Both BAC and the Royal Aircraft Establishment at Bedford and Farnborough co-operated in the tests.

(a) Object of the tests

1. To investigate the possibility of the stall warning system having operated during the initial pull-up as Double Echo star started to overshoot;

2. To obtain direct data on the pilot's instrument indications during the manoeuvre;

3. To examine in detail the characteristic features of the overshoot manoeuvre and to assess the effect of the revised overshoot procedure.

(b) Instruments used

The aircraft was equipped with a wide variety of special instruments including a Plessey-Daval Flight Data Recorder, an F and E Trace Recorder and a cine-camera aimed at the co-pilot's instrument panel. RAE provided and manned two kine-theodolite cameras to photograph the aircraft's flight path.

(c) Screening

For the overshoot tests removable screens were fitted round the co-pilot's position to remove all visual clues.

(d) Results

(i) Stall warning system

If the device had operated during the coarse initiation of Double Echo's overshoot, it would have provided an additional reason for the initial down pressure on the elevator control at about -8 seconds. The tests showed that so far as Echo Delta was concerned, this system did not operate when the aircraft was subjected to even more violent pull-ups than Double Echo's.

Calculations based on co-efficient of lift and free stream dynamic pressure tended to show that Echo Delta must have come much nearer to the stall than Double Echo. The fact that, even so, the stall warning on Echo Delta did not operate makes it unlikely that the warning was actuated in Double Echo.

(ii) Pilots' instrument indications

The airspeed and altitude traces from Echo Delta seemed to confirm that variations in pitch attitude produce false readings on the altimeter and airspeed indicator.

These traces did, however, also show that on Echo Delta at least there was some difference between the flight recorder readings and those of the pilots' instruments. If anything, the pilots' altimeter readings were even further from the true height (as calculated from normal acceleration) than the flight recorder. (See Fig. 11-2).

The standard vertical speed indicator appeared to give a fairly good representation of the true vertical velocity variations but with an approximately constant lag of about 2 seconds and lower peak values. Whilst this pattern of errors did not entirely confirm the deductions made in respect of Double Echo, it did show that the time-lag calculations were approximately correct. (See Fig. 11-3).

(iii) Characteristics of the overshoot procedure and the effects of the revised procedure

Five BEA pilots took part in this programme representing a wide variation in experience from senior pilots-in-command to recently qualified second co-pilots.

The results were as follows:

So far as ILS approaches were concerned, in the early stages of the approach there was no difference between the performances of the various pilots. In the later stages of the approach the more experienced pilots were markedly more accurate. A Principal Scientific Officer in the Blind Landing Experimental Unit of RAE Bedford explained the reason for this.

As the aircraft gets nearer to the source of the glide path beam, so the demands of the beam get more exacting. Due to the high gearing of the instrument, if these demands are followed precisely by the pilot it may result in too great a change in the flight path of the aircraft. The experienced pilot learns to anticipate this and to damp down the extent to which he follows the exact demands of the needle.

Less experienced pilots on overshoot using the old drill all showed a tendency to produce a single pitch and height oscillation or "hump" after initiation of the overshoot. This oscillation had similarities to Double Echo's trace between -7 and -4 seconds.

It seems that this was due to the immediate flap retraction and consequent trim changes, because when the same manoeuvres were carried out with the revised overshoot procedure, the "hump" disappeared. It may, however, have been that by the time these particular overshoots were performed, the less experienced co-pilots were becoming experienced. To the experience pilots it seemed to make no difference which form of overshoot procedure was used. The climb away was equally smooth with either.

2.- Analysis and Conclusions

2.1 Analysis

Evidence revealed that at the time of impact:

- all four engines were functioning correctly and were at full or nearly full power;
- the flaps were at a 6 $\frac{1}{2}^{o}$ position.

The possibility that the accident had been caused by the temporary sensory disorientation of the pilot was examined. There was little doubt that the co-pilot was affected by such disorientation. The climate which encouraged this was provided by the total lack of visual reference, the misleading information from the pressure instruments, a lack of attention to the artificial horizon and the fact that the co-pilot was tired and understandably anxious.

Other possibilities which might have contributed to the accident were examined.

(a) Sticking Director Horizon

A theory was advanced that the accident might have been caused by the pitch pointer sticking at some position above the artificial horizon and so misleading the pilot into the belief that the aircraft was climbing.

The evidence showed that the changes of the pointer jamming at positions other than the top or bottom of its travel are very remote. Since the pointer never reached the limits of its travel in either direction during an overshoot it was not considered that jamming of the co-pilot's artificial horizon was a possible explanation of the accident.

(b) Jammed elevators

The possibility that the elevators could have jammed in a down position at about 5 seconds before impact and then have been freed in time for the final unsuccessful pull-up at 1 ½ seconds was in any event very remote.

Further calculations made by BAC satisfied the Board that the elevators did not jam.

(c) Elevator overbalance

There was no evidence suggesting that the Vanguard aircraft has ever been prone to this type of trouble. The most likely cause of serious elevator difficulties of this sort would be the loss of the elevator curtains. Those on Double Echo had recently been renewed.

The Board did not regard elevator overbalance as a feasible possibility.

The Board concluded that a series of misfortunes combined to bring about the eventual crash. No single one of these on its own would have caused the accident.

The scene was set by the transmission of the wrong runway visual range to the aircraft. Had the correct value, namely 300 metres, been given, the pilot-in-command would have been prevented from making an approach, because 300 metres was below the permitted minimum. Furthermore, the 350 metres minimum was itself too low, as it now appears.

After two unsuccessful approaches to land, the pilot-in-command would have been wiser to await an improvement in visibility, as he had originally intended, before making a third attempt. It was the successful landing by Echo Delta on runway 28R which understandably encouraged him to make the decision which he did.

The co-pilot was probably not at his freshest. It was his second consecutive night on duty. This was the third approach he had made. It was the end of a long and tiring day. Forty minutes had elapsed since the previous unsuccessful approach. Judging by the reconstructed flight path of the first two approaches and the record of the final approach and the initiation of the overshoot, his flying was not on this occasion as polished as it might or should have been.

On the third and final approach, whether it was because the pilot-in-command was not satisfied with the positioning of the aircraft or, more likely, because no sufficient visual reference was forthcoming, overshoot procedure was initiated. It was initiated by a coarse up-movement of the elevator by the co-pilot. Why he felt it necessary to execute such a violent manoeuvre it is impossible to say. He may perhaps have thought he was nearer to the ground than was in fact the case. He may have been too anxious to avoid violating the minimum critical height. Inexperience in executing the manoeuvre live in fog probably also played its part. If, as we think, he was paying too much attention to his pressure instruments, the readings which he derived from these during the pull-out would have accentuated the fear that the aircraft was too low.

No one until a fortnight before this accident had questioned the suitability or safety of the overshoot procedure, nor had anyone suspected that there might be latent hazards in overshooting. This procedure demanded that the pilot-in-command should select flaps up to the 20° position and undercarriage up as soon as the overshoot was started. Such procedure, even when carried out correctly, was apt to cause unnecessary distraction at a critical moment, when it was essential that all three pilots should have their attention devoted to the flight instruments.

On this occasion the procedure was not carried out correctly. The design of the flap selector quadrant was such that an incorrect selection was easy, and there was no doubt that the pilot-in-command selected flaps up beyond 20°, either to 5° or to fully up. The movement of the flaps up beyond the 20° position would have affected the pitch attitude of the aircraft and provided a further difficulty, albeit small, for the pilot.

At this moment the co-pilot was rotating the aircraft too abruptly, and was busy transferring his concentration from the precise ILS coupled instrument to the more generalized display of air speed incator, vertical speed indicator, altimeter and artificial horizon. He had not by then had any opportunity to re-adjust his pitch scale, on which up to that moment he had been partially relying. The director horizon had ceased its directing function and had become a conventional artificial horizon with a limited amount of travel on which substantial changes of pitch attitude were reflected by only small movements.

The co-pilot almost certainly shared with other co-pilots the tendency to pay more attention to his pressure instruments than their accuracy warranted. This was due to insufficient emphasis during training on the misleading effect of these instruments, and to the fact that no one had up to that time voiced any suspicion that additional inaccuracies might be caused in them by rapid changes of aircraft pitch.

At about 9 seconds before impact he relaxed up-pressure on the elevator because his speed appeared not to be building up and his rate of climb was more than adequate.

At 6 seconds before impact the indicated airspeed had still only risen to 137 kt from its lowest point of 134 kt at -14 seconds, the rate of climb according to the vertical speed indicator was still 850 fpm and the co-pilot therefore put the aircraft's nose further down.

At 4 seconds before impact the vertical speed indicator was still probably showing a substantial rate of climb, and the altimeter a gain in height, although the aircraft was in fact losing height. The co-pilot was misled into continuing and increasing his down pressure on the elevator. A measure of disorientation probably contributed to this mistake.

If at this point any one of the pilots had looked at the artificial horizon, the true picture would have been apparent. That they did not do so was probably due to the fact that attention was distracted by the movement of the flaps, which would at this time be shown as retracting towards 5° when they should not have been. Thus during the crucial time, between about 5 and 2 seconds before impact, the system whereby the co-pilot's actions should have been monitored broke down, the co-pilot's over-dependence on his pressure instruments whent unchecked, and by the time that anyone realized what was going wrong, it was too late.

2.2 Conclusions

(a) Findings

The crew was properly licensed. The crew was suffering from the normal tiredness one would expect in the circumstances.

The aircraft had a valid certificate of airworthiness and had been properly maintained and loaded.

The training programme had the following defects. Insufficient emphasis had been laid on the potentially misleading effect of pressure instruments and on the necessity of using the artificial horizon as the primary flight instrument in overshooting. Too great a reliance had probably been placed on simulator training, too little on training in the air under screens.

The runway visual range minimum of 350 metres was too low. Furthermore, the pilot-in-command of the aircraft was told that the runway visual range was 350 metres when in fact it was 300 metres.

The pilot-in-command moved the flap selector too far on the initiation of the overshoot. The flap position immediately before the accident was 6 $\frac{1}{2}$° when it should have been 20°.

The flap selection lever quadrant was so designed as to make mis-selection easy.

(b) Cause or Probable cause(s)

The cause of the accident was attributed to pilot error due to the following combination of events:

(i) low visibility

(ii) tiredness

(iii) anxiety

(iv) disorientation

(v) lack of experience of overshooting in fog

(vi) over-reliance on pressure instruments

(vii) position error in pressure instruments

(viii) lacunae in training

(ix) unsatisfactory overshoot procedure

(x) indifferent flap-selector mechanism design

(xi) wrong flap-selection

3.- Recommendations

The Board made the following recommendations:

- Screens should be used during blind-flying training.

- If technically possible, the present director horizons should be replaced by more up-to-date instruments with a greater range of travel and more obvious failure warning flaps. The co-pilot's instrument display should, if possible, be equipped with the same type of servo-altimeter as that now provided for the pilot-in-command.

- Research should be made to determine how far the pressure instruments on the Vanguard are rendered inaccurate during rapid changes of pitch attitude by position error of the static vent. Depending on the results of this research the necessary modifications should be made to the Vanguard simulator.

- The system whereby no positive approval of an operator's weather minima is required to be given by the Ministry is unsatisfactory. It gives power whilst withholding responsibility. Positive approval or disapproval should be required.

- Frequent regular checks should be made of the runway visual range lighting system to ensure that it does not materially differ in intensity from the runway lighting proper.

- The flight data recorder should include a parameter for elevator angles.

ICAO Ref: AR/044/65

ACCIDENT TO VANGUARD, G-APEE, OF BRITISH EUROPEAN AIRWAYS, AT LONDON (HEATHROW) ENGLAND, ON 27 OCTOBER 1965

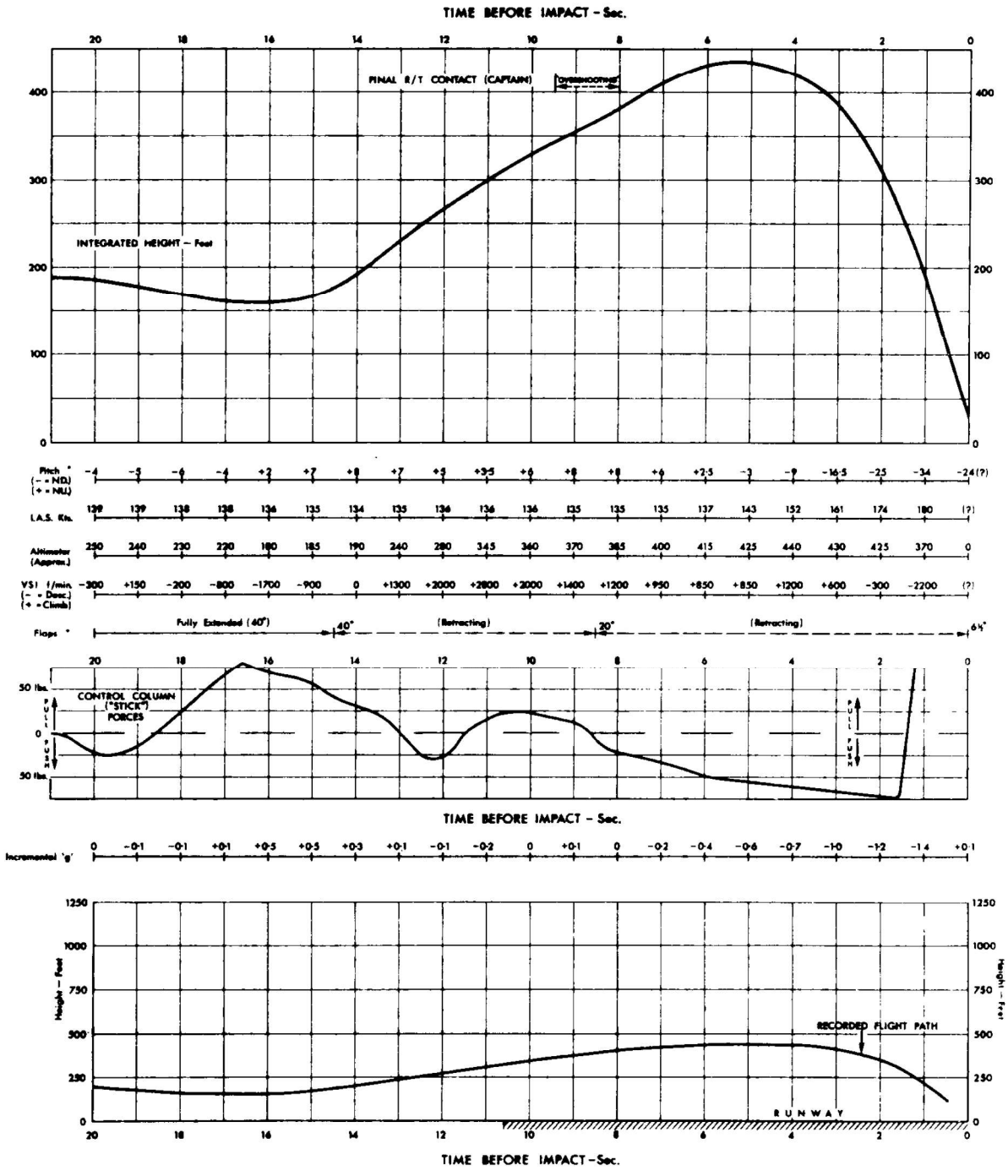

Fig. 11-1

ACCIDENT TO VANGUARD, G-APEE, OF BRITISH EUROPEAN AIRWAYS, AT LONDON (HEATHROW) ENGLAND, ON 27 OCTOBER 1965

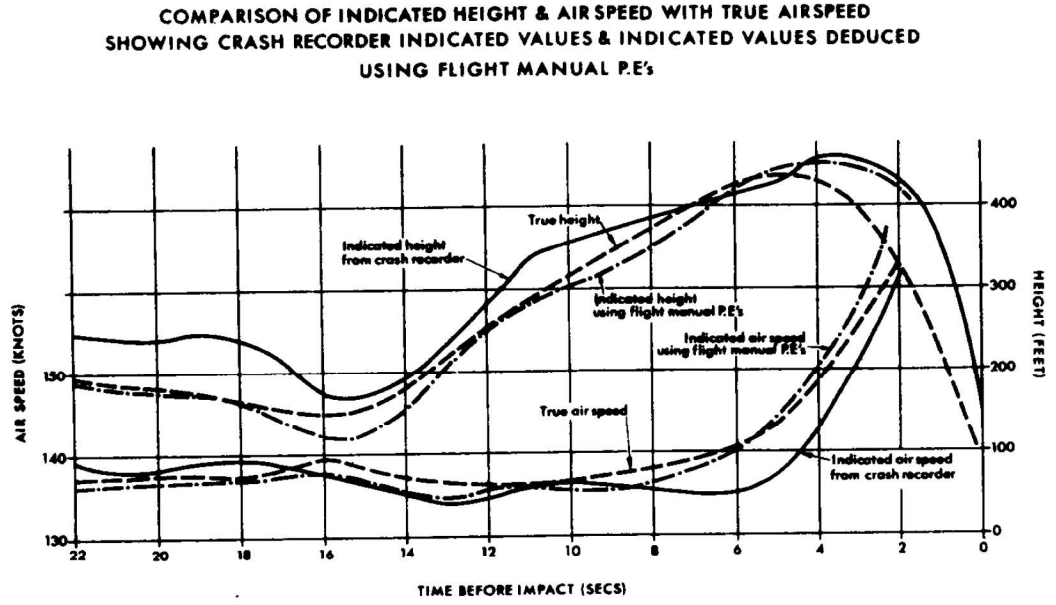

Fig. 11-2

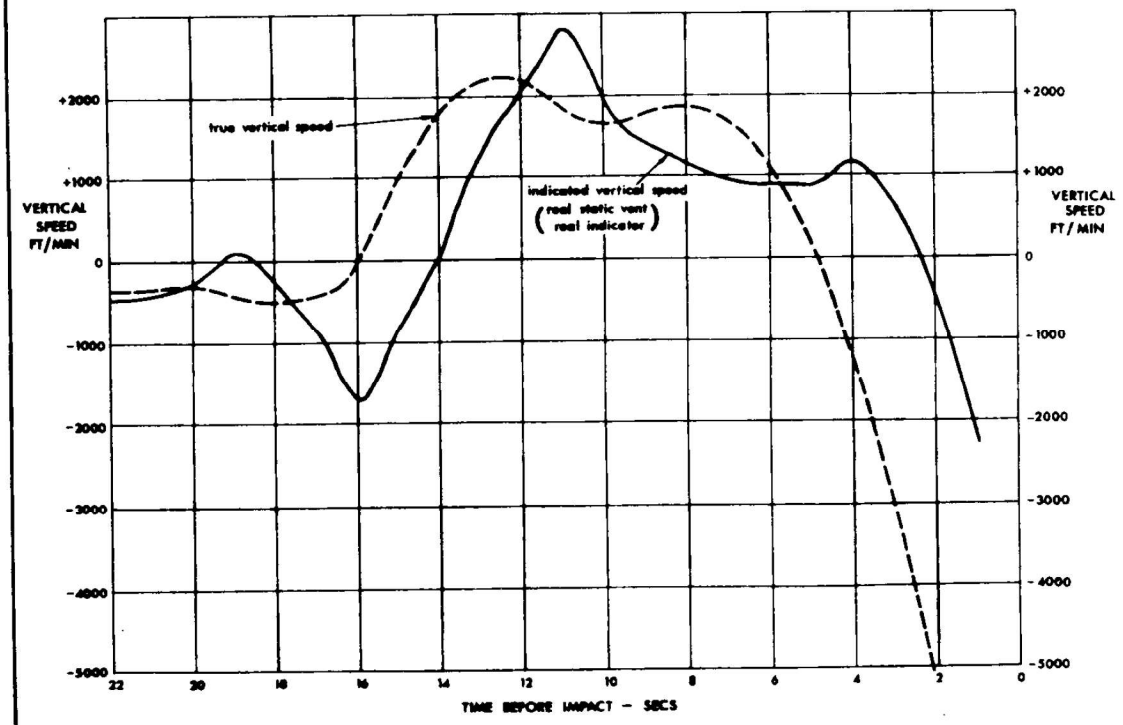

Fig. 11-3