ACCIDENTS INVESTIGATION BRANCH
Department of Trade and Industry

Trident I G–ARPI
Report of the Public Inquiry into the causes and circumstances of the accident near Staines on 18 June 1972

ACCIDENTS INVESTIGATION BRANCH
Department of Trade and Industry

Civil Aircraft Accident Report 4/73

Trident I G–ARPI. Report of the Public Inquiry into the causes and circumstances of the accident near Staines on 18 June 1972

CORRECTION

Page 12, paragraph 2, line 4: Delete 'say 30 knots' and insert 'say 60 knots'.

London: Her Majesty's Stationery Office
1973

LONDON: HER MAJESTY'S STATIONERY OFFICE
1973

List of Civil Aircraft Accident Reports issued by AIB in 1973

No.	*Short title*	*Date of publication*
1/73	Douglas DC3 PH–MOA at Southend Airport, June 1971	February 1973
2/73	Bolkow BO 208C Junior G–ATVB near Hambledon, Surrey, January 1972	February 1973
3/73	Beagle 206 Series 2 G–AVAL at Chouppes (Vienne) near Poitiers, France, March 1971	May 1973
4/73	Trident I G–ARPI near Staines, June 1972. Report of the Public Inquiry	May 1973

Royal Courts of Justice
London
14 April 1973

The Rt Honourable Peter Walker MBE MP
Secretary of State for Trade and Industry

Sir,

On 18 June 1972 Trident I aircraft G–ARPI crashed near Staines. A Public Inquiry was directed to be held into the causes and circumstances of that accident.

On 14 July 1972 the Lord Chancellor appointed me to be the Commissioner of the Inquiry and Sir Morien Morgan, CB, FRS and Captain J W Jessop to be assessors.

We held the Inquiry at the Piccadilly Hotel, W1, starting on 20 November 1972 and continuing, with a break for the Christmas holiday, until 25 January 1973.

We had the advantage of visiting the BEA training centre at Heston, where we had demonstrated to us the Trident I simulator; the Hawker Siddeley rig at Hatfield, and the hangar at RAE Farnborough, where the Accidents Investigation Branch had re-assembled so far as possible what remained of the aircraft.

Captain Evans of BEA and two co-pilots very kindly demonstrated for our benefit three take-offs and landings in a Trident I at Heathrow on 14 December 1972.

We are indebted to all those concerned for the willing co-operation which has marked each stage of the Inquiry. Without that co-operation our task would have been even more formidable than in fact it was. We wish to pay special tribute to the Accidents Investigation Branch team whose painstaking thoroughness had solved many of the problems before our Inquiry even started.

I have the honour to present my report, with which my assessors agree.

I have the honour to be
Sir
Your obedient Servant

Geoffrey Lane

Contents

Chapter I. Introduction

Trident I G–ARPI (called throughout this report by its call-sign 'Papa India'), owned by British European Airways (BEA) and operated by them under a valid air operator's certificate, crashed in a field near Staines at 1611 hours* on Sunday, 18 June 1972, shortly after taking-off from London (Heathrow) en route for Brussels on a scheduled flight. All those on board suffered fatal injuries.† They comprised three pilots, two stewards, one stewardess and 112 passengers, of whom three were BEA positioning crew in transit. One of these was seated in the P4 position on the flight deck. The aircraft had a valid Certificate of Airworthiness and a valid Certificate of Maintenance.

* All times are in GMT.

† Their names are set out in Appendix A.

Chapter II. Narrative

(i) Flight Data Recorders

Almost all of the detailed facts set out in this report as to the speeds, height, tail plane angles, flap and droop movements, in short the handling and behaviour of Papa India, were derived from one or other of the two Flight Data Recorders (FDR) carried on the aircraft. The information recorded on the parameters of the mandatory FDR was supplemented in several valuable respects by that of the quick access cassette recorder which BEA have installed in their Tridents. This, though not crash-protected, was recovered intact. A good preliminary readout was obtained within a few hours of the crash at the BEA Flight Recorder Unit at Heathrow. It is, however, necessary to process the raw data to allow for position and calibration errors on the various parameters. After consultations between the Accidents Investigation Branch (AIB), Hawker Siddeley Aviation (HSA), BEA and the Civil Aviation Authority (CAA), the HSA Aerodynamics Department undertook this task, using a suitable computer programme. All four parties agree that the results represent the most accurate interpretation possible of the raw data, and there has been no valid suggestion that the figures so deduced are other than substantially accurate.

The value of that information to this Inquiry can hardly be over-stated. Without it most of the basic facts which have rightly been accepted by everyone as correct would have been the subject of inconclusive debate. Graphs illustrating the various resulting parameters and events of the flight taken from the FDRs are to be found at Figures 1 and 2.

(ii) Weather

The weather at Heathrow at the time was dictated largely by a cold front approaching south-eastwards across England, and lying some 30 nautical miles distant. The main layer of cloud was 8/8 with its base at 1,000 feet. There were small amounts of cloud below this, the lowest being at 600 feet. It was raining. Surface wind was 210°/17 knots. There was considerable turbulence. It follows that at the crucial times the aircraft was in cloud and the crew had no visual reference.

(iii) Aircraft loading

At the time of start-up there were 8,550 kilograms of fuel on board Papa India. The estimated fuel weight for take-off was 8,200 kilograms. Since the engines were running for some minutes before taxying the actual figure for fuel on board would be slightly lessened. After engine start last-minute load

alterations were made in order to keep the figure below the permitted Maximum Zero Fuel Weight for the aircraft of 41,730 kilograms. In fact, despite the alterations, the weight was 24 kilograms too great. A study of the Balance Chart shows that the centre of gravity was marginally forward of the BEA limit, although within the *Flight Manual* specified range.

Neither of these two comparatively trivial errors had any bearing on the accident. They had no effect on aircraft performance, and having been mentioned can be disregarded.

(iv) Rescue services

The aircraft crashed in a field on the Staines side of the A30 Staines By-Pass opposite the King George VI Reservoir. The crash was witnessed by Trevor Burke aged 13 who was on a footpath close-by. With great presence of mind he ran and told Mrs Castledine who lives about a quarter of a mile away. Mrs Castledine was previously a nursing sister at Ashford Hospital and was familiar with accident procedure. She was one of the first on the scene and she made heroic efforts amidst the wreckage to help any of the victims who were still alive. Her actions cannot be praised too highly. However, the decelerative forces of the impact were too great for the human frame to survive. Only one person was alive (though deeply unconscious) on arrival at Ashford Hospital and he died soon afterwards.

From 1620 hrs onwards there was a rapid build-up of police and other rescue services. The field as it happens is on the boundaries of three separate police divisions and there was consequently no shortage of manpower.

The first ambulance on the scene was a Berkshire vehicle which happened to be passing. The crew notified their control headquarters and went to assist. Surrey ambulance vehicles began arriving at 1626.

The first fire-engine arrived at 1627, followed soon afterwards by a number of other vehicles.

The field was sufficiently inaccessible to prevent all but the most persistent sightseers from reaching it. The police were successful in controlling spectators, and contemporary reports that members of the public had impeded rescue services by their presence near the scene are not borne out by the facts.

All the services involved acted with commendable despatch.

(v) The flight

The flight crew consisted of Captain Key, Second Officer (S/O) Ticehurst and S/O Keighley. Their respective flying experience is examined in detail hereafter.* They were on stand-by duty and had only been called upon to undertake this assignment because the originally designated crew had been delayed.

During the flight Captain Key was in the first pilot's (P1) position on the port side, S/O Keighley in P2's on the starboard, S/O Ticehurst in the central P3 position slightly aft of the control pedestal and of P1 and P2, and Captain Collins in the P4 or jump seat behind the Captain. Captain Key was the handling pilot.

* See Chapter IV C(iv).

Apart from the probability that in the particular conditions he would have elected to handle the aircraft himself, an examination of the lamp filaments in the P1 'azimuth' window showed that at the time of the crash the compass switch was turned to port, thus indicating that P1 was flying. It is true that after the crash the switch itself was found in the starboard position, but it is easily moved and footprints nearby showed that rescuers had had to trample over this part of the flight deck and must have moved the switch in the process.

The flight was the scheduled passenger service number BE 548 to Brussels. Start-up clearance was given at 1539 hrs for a scheduled departure time of 1545. Push-back (ground handling of the aircraft from its parked position) was not requested until 1600 hrs. This was due to load re-adjustment. Clearance to taxi was given at 1603 hrs.

Evidence of R/T messages between aircraft and control is taken from the Air Traffic Control recordings, whereas evidence of the aircraft's movements is derived from the Flight Recorders. There is no common time-scale between the two sources. Every effort has been made to correlate the two accurately, but aircraft times may be possibly up to 5 seconds later than those shown.*

At 1606 hrs a Dover One Standard Instrument Departure clearance was given with instructions to select the transponder (radar identification device) to standby 6615. This was acknowledged. At 1606 hrs 53 secs the crew reported ready for take-off and Papa India was cleared for take-off on Runway 28R. There was then a delay of 42 secs† after which the aircraft was finally cleared for take-off at 1608 hrs 24 secs. Brake-release was probably 1608 hrs 30 secs.

The standard BEA practice for this particular flight involved a take-off with 20^{o} flap, leading edge droop extended and the engine thrust at settings below full power. After take-off speed should be increased to the initial climb speed V_{NA} (ie, take-off safety speed, V_2 plus 25 knots). The scheduled value of V_{NA} for this flight was 177 knots Indicated Air Speed (IAS). At 90 seconds from brakes-off flaps are to be selected fully up and the engine thrust reduced to the noise-abatement settings. At 3,000 feet climb power is to be set and then as the aircraft accelerates and reaches 225 knots the leading edge is retracted and the en route climb established. The minimum droop retraction speed is placarded by the lever and is well-known to all pilots. Also well-known is the injunction against retracting the droop in a turn.

The actual sequence of events derived from the FDR readout in the case of Papa India was very different. Times are given in seconds from brake-release.

The take-off was normal and at 42 seconds the aircraft rotated, leaving the runway 2 seconds later at 145 knots IAS. At 63 seconds the autopilot was engaged 355 feet above the runway at 170 knots IAS; the IAS speed lock was selected shortly thereafter. At 74 seconds the aircraft started a 20^{o} banked turn to port towards the Epsom Non-Directional Beacon (NDB). At 83 seconds Captain Key reported 'Climbing as cleared'. He was then instructed to change frequency and contact London Air Traffic Control Centre on 128.4 MHz.

* The Chronology is shown in tabular form at Figure 3.

† It is just possible that the delay was caused by trouble with the stall recovery low-pressure warning light. See Chapter III B(vi)(c)

At 93 seconds the noise-abatement procedure was initiated. On the assumption that Captain Key was the handling pilot, this would involve S/O Keighley selecting the flaps fully up and operating the thrust levers to reduce power to the pre-calculated figure. At 100 seconds Captain Key called 'Passing 1500' and at 103 seconds the aircraft was cleared to climb to Flight Level 60 and to 'squawk' 6615 on the transponder. This message was acknowledged by Captain Key at 108 seconds with the terse call 'Up to 60'. This was the last message received from Papa India. In the wreckage was found S/O Ticehurst's log, on which he had duly entered this clearance up to Flight Level 60.

At second 114 when the airspeed was 162 knots and the altitude 1,772 feet, the droop lever was selected up putting the aircraft into the area of the stall as the droop started to move. At second 116 the stick-pusher stall recovery device operated, causing the autopilot automatically to disengage and the nose of the aircraft to pitch down and the stick-push to cease as the incidence decreased. Since the elevator trim would stay at its position on autopilot disengagement which at that speed with the droop up would be tail-heavy,* the incidence then increased causing a second stick-push at second 124 and a third at second 127. At second 128 the stall recovery system was manually inhibited by pulling the lever. The aircraft then pitched up rapidly, losing speed and height, entering very soon afterwards the true aerodynamic stall and then a deep stall from which at that height no recovery was possible. Impact was at second 150.† It may be of importance to note that after the first stick-push the bank was taken off.‡

Upon examination of the wreckage it was found that each of the four men on the flight deck had had his head-set plugged in and that all four switches were set to 'intercom'. Captain Collins was found to be holding in his right hand a can of Aerosol Air Freshener. This type of can is standard issue to all freighter captains of whom Captain Collins was one.

Captain Key's seat, contrary to earlier assumptions, was in the notch where one would expect it to be had he been the handling pilot. It had not been slid back prior to impact.

* The aircraft was in effect trimmed into the stall.

† The deduced ground-track of the aircraft is illustrated at Figure 4.

‡ See Figure 3 under 'Bank-angle'.

Chapter III. The mechanical factors

A. SPEED

One of the most important facts disclosed by the FDR was the consistent failure by the handling pilot to achieve the appropriate speeds for the relevant stages of flight. Had the speed been only some 10-15 knots higher when the droops were retracted, recovery would have been comparatively simple.

The IAS at the time of autopilot engagement was some 7 knots below the normal noise-abatement climb speed (V_{NA} of 177 knots. The noise-abatement procedure was initiated at 93 seconds (nominal time 90 seconds) by retraction of the flaps to fully-up. The IAS at this point was 168 knots (9 knots below V_{NA}). After the thrust had been reduced as part of the noise-abatement procedure there was a further drop in speed until at 105 seconds it had fallen to 157 knots or 20 knots IAS below V_{NA}.* At this stage it was just possible that the stick-shaker may have operated momentarily. There was then a rise to 162 knots at second 114 when the droop selector lever was moved to the up position with the aircraft in a banked turn.

We deal with the question of any possible malfunction of the autopilot at a later stage. Apart from that, it was important to know whether or not such a large discrepancy between target and actual speeds was or was not to be expected in general, or in respect of Papa India or in respect of Captain Key.

(i) Comparison of accident flight with other Trident flights

The Airworthiness Division of the Civil Aviation Authority (CAA) carried out a series of analyses of other similar Trident flights with this aim in view. A sample of 100 flights during 1968 was taken and from this it seems from data available that a speed error/loss of 20 knots below V_{NA} might at that time have been expected in around 1 in 1,000 flights (possibly 1 in 3,000 flights with manual and 1 in 400 flights with autopilot).

A further check was made of 34 flights taking place between January and March 1972. It emerged from this check that the maximum speed error/loss was 12 knots. So far as can be gauged the trend was such that a 20 knot discrepancy would not have been found more often than about once in every 10,000 flights. The flight data recordings for this particular sample did not allow a distinction to be drawn between manual-controlled and autopilot-controlled flights.

* See Figure 1.

(ii) Previous flights of Papa India

A similar analysis of the flights of Papa India during the 16 days up to and including 18 June 1972 was made by CAA. Thirty six flights, all from Heathrow were looked at and compared with the 100 Trident I flights analysed earlier. Results show that the characteristic fall-off in speed after flap retraction was about the same as that observed in the 1968 sample. The actual speeds, in terms of speed error from the scheduled value, were broadly similar to the earlier flights under autopilot control, but the improvement noted for flights under manual control in the 1968 sample was less evident in Papa India.

A suggestion was made that the autopilot system was working sluggishly on Papa India prior to the accident flight. The records show that whilst in general the performance of Papa India compares favourably with other aircraft, yet the highest speed losses after flap retraction on Papa India occurred within the 24 hours prior to the accident. In fact two of these were cases when the aircraft was on manual control and this, coupled with the evidence of Captain White who detected nothing amiss with the autopilot during his flight in Papa India on the morning of 18 June, satisfies us that the larger than usual losses must have been due to the turbulent conditions and that the autopilot was in no way to blame.

(iii) Previous flights where Captain Key was in command

From data supplied by BEA of flights by aircraft of which Captain Key was in command during the days preceding the accident it was possible to compare performances with the corresponding data for other Trident I flights. The sample was small, but indicates that Captain Key tended to engage autopilot at a speed and height marginally lower than the average. The speed losses after flap retraction are similar to the average. The maximum speed errors occurring after flap retraction are typical for the take-offs where power is reduced to noise-abatement levels. On flights where thrust is reduced only to normal climb power the speeds are above V_{NA} both at and after flap retraction in every case.

Summary

1. The low airspeed after flap retraction resulted from a combination of lower than normal airspeed throughout the initial climb and a greater than normal error after flap retraction and power reduction. A discrepancy of anything like this amount is a very rare occurrence indeed.
2. The average speed loss after noise-abatement for flights by Papa India in the 16 days leading up to the accident is similar to that on other Trident I aircraft. Three of the largest speed losses occurred during the 24 hours preceding the accident. This, we believe, was due to the prevailing turbulent conditions.
3. Captain Key's speed control on other flights was at least as good as that of other pilots.

B. THE AIRCRAFT

(i) General

Both Hawker Siddeley and BEA are justly proud of the Trident and the record it has earned. BEA can point to the fact that this is the first fatal accident to a passenger-carrying Trident in more than half a million flying hours. It has helped BEA to maintain its position in what the Edwards' Report (paragraph 88) described as the 'top league of international aviation'.*

We have heard nothing but praise of the aircraft from all quarters. It is a reputation which is well deserved and nothing we have heard in this Inquiry has done anything to tarnish it.

The prototype first flew in January 1962. HSA then in accordance with the usual procedure drew up a Schedule of Flight Tests and had it approved by the Certification Authority (then the Air Registration Board (ARB)). The test programme having been flown, reports on it were duly submitted. At this stage, the ARB flies its own test programme, varying in intensity according to the nature of the aircraft concerned. In the present case these tests were completed by February 1964 when the first Trident was certificated and registered. The test flying for the ARB was all done by Mr Davies (the very experienced ARB Chief Test Pilot). Everything went smoothly. For a high-speed jet transport the Trident handled well (a view endorsed by line pilots), and met all the airworthiness requirements without difficulty. It did not have to seek permission for any variations from standard requirements or the provision of 'equivalent levels of safety' as most if not all aircraft in the past had done.

(ii) Stall warning and recovery

In the case of older and more conventional aircraft the approach to stalling incidence was usually heralded by a noticeable buffeting as the airflow over the wing-root became disturbed; this was followed, if no corrective action was taken, by a sharp nose-down pitch as the aircraft in fact stalled. Thus the designer helped nature to provide an adequate and unmistakable stall-warning system which a pilot would disregard at his peril. It could not, in the nature of things, operate falsely because it was itself part of the process of the aerodynamic stall.

In the quest for aerodynamic efficiency, however, these characteristics had largely to be eliminated. The Trident was subject to some buffeting on approach to stall in its clean configuration but not with droops extended; there was a slight nose-down pitch at stalling incidence which rapidly became a nose-up pitch.

It therefore became necessary for the designers to restore to the aircraft by artificial means the natural tendencies they had removed. Two devices were incorporated, separate but complementary, the stall warning and the stall recovery systems. Each of them is dependent upon the readings provided by

* *British Air Transport in the Seventies,* Report of the Committee of Inquiry into Civil Air Transport. Cmnd 4018. HMSO, 1969.

incidence probes, one on either side of the fuselage. The stall depends not only upon incidence but also upon the particular configuration of the aircraft (ie droop and flap setting). The stall warning and recovery systems take account of both these factors. They also take account of the upward pitch-rate, and operate at a decreased incidence in proportion to that pitch-rate to prevent overswing into the aerodynamic stall.

The stall warning (or stick-shaker) system is designed to operate at an incidence several degrees below the stalling incidence appropriate to any particular configuration. It activates an electric motor which in its turn causes both control columns to vibrate. The pilot is thus given a vivid warning that he is required to reduce the incidence at once.

If he fails to do so and continues his progression towards the stall, at an incidence very little lower than the true aerodynamic stall, the stall recovery (or stick-push) system will operate. This is a pneumatically-controlled ram which physically pushes the control columns forward with considerable force. It reproduces therefore the sharp nose-down characteristic of the conventional stall and at the same time provides a bonus in that it takes on behalf of the pilot the first remedial action for him, sharply decreasing his angle of incidence. Thereafter it is up to him to assist the system by flying a recovery. If he does not and his incidence again rises he will get another stick-shake and stick-push, and so on, unless he pulls the stall recovery override lever and thereby, as it is said, 'dumps the system'.

HSA, of course, recognised the difference in urgency between the two forms of warning, and the relative importance of a malfunction of either, and so incorporated a difference in their method of operation. The stick-shaker will be activated if only one of the two probes is indicating the critical incidence. On the other hand, before the stick-pusher can operate, both probes must so indicate. There is no doubt that these are highly effective devices. Apart from teething troubles affecting the stick-shaker mechanism, which are the subject of discussion later, the stick-shaker has in recent years proved, broadly speaking, to be reliable and effective. The stick-pusher, by reason of the design, is even less likely to operate falsely. Certainly it has never been known not to operate when it should.

The systems inevitably suffer the disadvantage of most man-made imitations of nature, that is that they are known to be imitations and are known to be not infallible, with all that means in terms of credibility.

There is a practice of providing mechanical devices of this nature with means whereby they can be inhibited in case of dangerous malfunction. The stick-shaker can be disconnected by operation of the relevant circuit-breakers on the systems panel. The stick-pusher has its own stall recovery override lever on the port side of the central control pedestal.*

* See frontispiece.

The circuit-breaker system for the stick-shaker was at a later stage modified from the original design to incorporate two magnetic indicators ('dolls' eyes') placed on the systems panel behind P3. By looking at these it is possible to determine which of the two or whether both port and starboard stick-shaker mechanisms have operated. If it is suspected that the operation is bogus and only one dolls' eye has been activated, that side of the system can be isolated by pulling the appropriate circuit-breaker, still leaving the other side of the stick-shaker mechanism and the whole of the stick-pusher system effective.

The original design had been such that if there was a false or suspected false operation of the stick-shaker the instructions were that the whole system including the stick-pusher should be inhibited by pulling the stall recovery override lever. This was modified by the introduction of the dolls' eyes and their attendant mechanism in 1966.

We heard some criticism of the reliability of the stall warning and recovery systems and, what is by no means the same thing, suggestions that pilots as a whole regarded the two systems as unreliable, and were apt to regard their operation as more likely to be spurious than genuine.

Accordingly we examined in some detail the history of the systems as experienced by BEA. It should be noted that reports on stick-shaker function will all or nearly all be occasions where the captain regarded the operation as being spurious. Whether he was right or whether the operation was in fact genuine is not always easy to determine. For example, two pilots who gave evidence realised for the first time as they recounted their particular experiences to us that the stall-warning was probably genuine. With that proviso the facts, as far as we could determine them, are these:

So far as stick-pushes are concerned, including the recorded ones and the known unrecorded ones, there have been between 1965 and 1973 ten push incidents, including Papa India. One was on the ground in 1966, one was at 60 knots on take-off in 1965. Of the remaining eight, four were certainly genuine including Foxtrot Hotel* and Papa India, a fifth (in 1966) was in training and was very likely genuine.

Only three were both in the air and false during the eight years. Of these, one was subsequent to Papa India and the other two were each on the same aircraft as far back as February 1966. Thus in the 6½ years leading up to June 1972 there have been no false stick-pushes in flight.

Stick-shake incidents are of course more common, both because of the nature of the mechanism and because the incidence at which that mechanism operates will be reached on more occasions. Thanks to research and modifications they have decreased in frequency over the years. In 1966 they numbered 1.7 per thousand hours and in 1972 0.65 per thousand hours. It was said that on the basis of the statistics it is likely that a pilot will experience a stick-shake on an average only once in every three years.

* See Chapter IV D.

From this it emerges that there were, as one would expect, teething troubles in the early days afflicting both systems; that throughout, owing to the deliberate difference in designs already explained, the stick-shaker did on occasions operate when it should not have done; that there was a marked decrease in such events after about 1966; that so far as the stick-pusher was concerned, after 1966 it was almost without exception reliable.

So far as pilots' attitude to the reliability of the systems is concerned we deal with that in more detail in Chapter IV D(iii). Suggestions that most pilots on getting a stick-shake would have immediately reacted by overriding the stick-pusher are not borne out by the evidence. However, we doubt if pilots' attention was sufficiently drawn to the difference in design form between the two systems, although the information can be extracted from the *Flight Manual.* This may have resulted in a feeling that if the stick-pusher operated in circumstances which appeared to the pilot to be doubtful, the system should not get the benefit of the doubt. Experience shows that it should be believed. Ideally the prompting of the stick-pusher system should be obeyed to the limits of safety. However, in the particular circumstances existing in Papa India, it was probably too much to expect that this precept should have been observed.

HSA provided us with information on the recovery capabilities of the aircraft in the circumstances which existed in Papa India.

A satisfactory recovery should have been made if any of the following actions had been taken:

1. Speed had been increased by ten knots in the noise-abatement sector.
2. The droop had been selected down at any time before dumping the recovery system.
3. The control column had been held forward of trim position after stick-push.
4. The stick-pusher had been allowed to operate without interference until 200 knots was achieved.

In all these cases, of course, application of power assists the recovery. Method 4, though technically feasible, would never in practice be adopted.

(iii) High-lift devices

The higher the speed in level flight and the greater the wing-loading, the more necessity there is for some method of enabling the aircraft to take-off and land at a reasonable speed; in other words to lower the speed at which it will stall.

The conventional trailing edge flaps go some way towards overcoming this difficulty, but these on their own would not have been enough to make the Trident acceptable. The Trident was the first British civil aircraft to have retractable leading edge high-lift devices fitted. These for purposes of convenience and brevity have throughout this report been called 'droops'.* They

* Trident II aircraft are equipped with slats rather than droops. The difference between the two devices is not relevant to this report.

consist of three separate but interconnected devices all operated by one lever on the central control pedestal.* In lay terminology they are as follows: first, the droops proper which are hinged at the bottom of the leading edge of the mainplanes and move outwards from the top when actuated; secondly, the droop sealing-plates which move into position to close the resulting gap between the upper edge of the mainplane and the trailing edge of the droops, and thirdly Kruger flaps inboard of the droops. These are in the nature of leading edge flaps, hinged at the top and extending downwards when operated. Their combined efficiency can be gauged by the fact that in level flight at a weight of 50,000 kilos the retraction of the droop in Papa India raised the stalling speed by about 30 knots.

We use that as a simple illustration, not overlooking the fact that it is incidence which primarily determines the point of stall, though from the pilot's point of view speed may be the dominant consideration. It follows that if the droops are retracted at say 30 knots below the safe droop-retraction speed of 225 knots the aircraft will be put immediately into a stall situation.† This was called throughout the Inquiry a 'change of configuration stall', though that is not a term of art.

It may be noted that retraction of the droops markedly reduces the incidence at which the wing stalls, whereas retraction of the trailing edge flaps results in relatively little change in stalling incidence. In consequence droop retraction at an unduly low speed is a particularly powerful method of propelling the aeroplane quickly into the stalling regime, treating the stalling regime as the region of wing incidence equal to or greater than that of the initial stall warning. This holds good if the initial stall warning is a natural buffet followed by a true aerodynamic stall and a nose drop; or, as in the case of the Trident, where we have an artificial stick-shake, induced by configuration monitored sensors, followed by a mechanically induced stick-push. Retraction of the droops at an unduly low speed is indeed a recipe for an almost simultaneous stick-shake and stick-push.

Premature retraction of the trailing edge flaps, with subsequent rapid sink of the aeroplane and a possible entry into the stall regime thereafter, can also obviously have disastrous consequences.

There is no need to discuss further the conventional trailing-edge flaps which were at all material times of flight retracted, save to say that the flap lever is sited adjacent and to the right of the droop lever on the central control pedestal.*

Each lever has to be moved in the same direction (inboard) to free it from its gate. The two knobs are dissimilar in shape.

(iv) Flap/droop baulk

It was recognised from an early period in the history of the aircraft that there might be confusion between the two levers (flap and droop) on occasions when prompt movement of one of them was necessary. Thus on overshoot when both levers might have been in the fully down position preparatory for landing, some sort of protection was necessary to prevent the pilot in the stress of the moment from retracting the droops instead of raising the flaps to the appropriate overshoot angle.

* See frontispiece.

† See Figure 6.

HSA first of all introduced a modification to guard against that particular possibility of mis-selection. BEA then asked for an extension of the modification to prevent the selection up of the droops in mistake for the flap on any occasion when the flaps had to be selected up. This was done, and the position on Papa India was that the droop lever was guarded by a physical baulk at all positions of the flap-lever greater than 7°. Once the flaps were raised from 7° to fully up the droop lever was unguarded. If the aircraft is allowed to climb away as designed regardless of noise-abatement, the length of time between flaps fully up and the achievement of droops-up safety speed (ie the time during which the droop lever is unprotected) is very short, and the aircraft would in any event be accelerating rapidly. The noise-abatement power-cutback after flap retraction extends the unguarded period by approximately 100 seconds.

The reason why no further baulk was asked for or incorporated was that at the stage of flight where the droop lever was unguarded there was no reason to select droop up or to select flaps up, and consequently a mistaken selection of droop in place of flaps did not seem to be a reasonable possibility.

A suggestion that HSA were requested during the very early days in 1964 to provide a more comprehensive baulk and failed to do so proved to be unfounded.

There is a limit to the amount of protective devices against pilot-error which should be provided on an aircraft. The designer has to strike a balance between the degree of danger involved on the one hand and the risk of over-complication on the other. Experience in operating the aircraft may alter that balance, and both the designer and the operator must keep such matters under review.

Certainly up to 1970 there was no reason for HSA or BEA to believe that the droop lever movement being unguarded during a period of some 2 minutes at this time constituted an unacceptable risk. No other aircraft in the world had or has a speed-operated baulk on the droop lever, although that is not the ultimate criterion. It seemed to be a period of flight when hurried or unconsidered movements were unlikely in the extreme. There was the added safeguard of BEA flight procedures which seemed to ensure that speeds would be adequate to prevent anything more than a stick-shake even if the droops were retracted out of time, procedures which further demanded that they should not be retracted until 225 knots and 3,000 feet were reached. At that time a designer or operator who had installed a speed-operated baulk could justly have been accused of over-elaboration and over-caution. One cannot baulk everything.

(v) The warning systems

These systems were designed by HSA in conjunction with BEA and the British Airline Pilots Association (BALPA) and with the help of material from the Applied Psychological Research Unit at Cambridge. They were tailored to fit the BEA concepts of the three-pilot crew and the 'monitored approach' technique.*

* See Chapter IV B(ii).

These required a centralisation of warnings to ensure that any significant malfunctions would be brought immediately to the notice of all crew members. The large number of warnings available made it undesirable to place them all on the front instrument panel. This difficulty was met by the provision of a Central Warning System (CWS). This is a sophisticated device which deserves more than the brief description which is all that is necessary for the present purpose.

One red and one amber flashing lamp are provided for each pilot's attention. These draw attention to the display panel, where the general nature of the fault is annunciated in one of 22 windows. Thereafter, determination of the specific failure is made by reference to the individual red or amber lamps located on systems panels or by checking to see whether controls are correctly set. These individual lamps are located on systems panels at the systems station, on roof panels above the pilots and on a control pedestal panel to the right of the thrust-levers. In each case the warning lamps are placed close to the controls affected. Their object is to direct the crew's attention to the particular action required at the point it is required.

The red alert lamps of course indicate the necessity for immediate action as opposed to the amber which merely demand attention.

The alert lamps can be cancelled by pressing the appropriate lamp or the 'push cancel' button on the display panel. The lamps located on the appropriate systems panel stay lit.

The individual warnings with which we are concerned are as follows:

(1) *Autopilot disconnect*

When the autopilot is engaged, any large input whether manual or from the stick-pusher will cause it to disconnect. This causes the red alert lamps to flash and the A/P window of the CWS display panel to illuminate. Disengagement of the autopilot can clearly at some stages of flight be critical, and consequently an audio warning is transmitted to each pilot's headset. This warning can be cancelled by pressing a button on the control column; this also extinguishes the red alert flashers and the red A/P in the display panel. Evidence shows that on Papa India the red alert lamp was illuminated on impact, indicating that the audio warning had not been cancelled.

(2) *Stall recovery warnings*

Special indications independent of the CWS were considered necessary to indicate to the pilots either that the stall recovery system was operating or that the system had failed.

Two warning lamps are located on each pilot's panel alongside the ASI labelled respectively STALL REC OPERATING, which is amber, AND STALL REC FAIL, which is red. The Stall Recovery Operating lamps light steadily when the stick-pusher is operating.

The Stall Recovery Fail lamps light steadily to indicate a failure of one half of the duplicated stall recovery system. Pressing either fail lamp whilst it is lit inhibits the recovery system which can then only be reset by maintenance engineers.

(3) *Droop out of position warning light (amber)*

This is sited immediately ahead of the droop selector lever and is designed to operate if excessive airspeed is approached with the droops extended or if too low an airspeed is approached with them retracted. It was not intended as a change of configuration stall-warning. Hence the amber rather than red.

Against this brief description, the warnings which would have presented themselves to the crew of Papa India would have been as follows:

(1) Within about 1 to 1½ seconds of the droop lever being moved, the droop out of position warning light, the flashing amber caution lamps and the amber CONTROLS window in the display panel illuminate. The CONTROLS window receives inputs from a number of systems, some of which are only relevant on the ground, some only on the approach to land. Apart from the droop out of position, the only other relevant matter at this stage of flight which could have caused the window to illuminate would have been a 'Q-pot' failure, which is extremely rare.

(2) About one second later the stick-shaker starts.

(3) Half a second thereafter the stick-pusher operates causing the Stall Recovery Operate lamp to light. A fleeting illumination of the red Stall Recovery Fail lamps is possible if there was a time-lag between the operation of the two wing-mounted droop surface microswitches.

(4) Almost simultaneously with this the autopilot disconnects automatically, causing the autopilot disconnect visual warnings, flashing and steady, and the operation of the audio warning.

The whole of this sequence of warnings would have operated in probably something less than three seconds from the movement of the droop lever.

The evidence was that so far as P1 and P2 were concerned this mass of warnings would not enable them to pick up the fault. Their attention would be 'tunnelled' on the ASI and attitude indicator in an endeavour to fly to what they considered to be a safe speed. That evidence was borne out by our own experience on the simulator. These considerations would not necessarily apply to P3.

(vi) Can mechanical malfunction be discounted?

There can be no dispute (and indeed there was none) that the critical events of flight were, first of all, the serious speed discrepancies at the material stages, secondly the movement of the droop lever at something like 60 knots below the placarded safety speed for that operation whilst the aircraft was in a banked turn, thirdly a failure by the crew to diagnose that the droop-retraction was the cause of the incipient stall, and finally the dumping of the stall-recovery system, which resulted from that failure to diagnose. The act of pulling the

dump lever must have been a conscious and deliberate act by one of those on the flight deck. It is, however, necessary to determine whether either the speed discrepancy or the movement of the droop lever could have been caused by mechanical malfunction.

(a) *Autopilot*

Nothing was wrong with any of the three engines. Calculations show that at noise-abatement cut-back they were delivering at least as much power as was expected. Nothing was wrong with the controls or control surfaces. The only other possible mechanical source for this sort of trouble would be the auto-pilot. This system was supplied by Smith's Industries Limited.

The autopilot was engaged in the pitch and roll channels at second 63 and the airspeed lock 3 or 4 seconds later when the aircraft was flying at 170 knots IAS. It disengaged automatically, as it was designed to do, at second 116 when the first stick-push occurred. Examination of the wreckage disclosed no physical evidence of malfunction in any part of the automatic flight control system. Captain Hadley flew Papa India on 17 June and Captain White, as has been said, flew it on the immediately preceding flight on 18 June. Neither detected anything amiss with the system and would indeed have reported it in the Technical Log if they had. There is no such entry.

That leaves the question whether there is anything in the history of the flight itself which indicates malfunction. The answer is no.

170 knots being the speed at which the autopilot is directed to fly remains the 'datum' speed until the pilot chooses, as he can, to dial up a different speed by moving the Speed Trim Wheel. It is improbable that there was any such alteration on this flight.

The 'target speed' is the speed at which the pilot is aiming to fly at any particular moment. This target speed was at the material times 177 knots IAS. 'Speed loss' is the amount by which the actual speed falls short of the datum (here 170 knots). 'Speed error' is the amount by which the speed falls below the target speed (here 177 knots).

So far as the autopilot is concerned it is only speed loss which is of any significance. This was never at any time greater than 13 knots IAS.

There was an initial loss of 2 knots between Air Speed Lock engagement and flaps up. Mr Davies agreed that there was nothing unusual in that figure. Thereafter there occurred a further loss of 11 knots IAS over a period of about 20 seconds.

In studies carried out by Smith's Industries it was possible to break down further that 11 knot loss as follows:

> 6½ knots IAS due to the cut-back of thrust by about 40 per cent at noise-abatement at 93 seconds, and 6-7 knots IAS due to horizontal turbulence. This breakdown was accepted by Mr Davies as probably correct. From all the studies carried out by CAA these figures are clearly in no way abnormal. We are satisfied that the automatic flight control systems were functioning properly according to their designed object.

(b) *Movement of the droop lever*

If it could be shown that the droop lever, by some fault either in design or maintenance, could have moved without human interference so as to cause the droop to retract, that might explain the accident. Two separate lines of reasoning emerged in support of that possibility. First, the inference to be drawn from an incident involving Trident II Foxtrot Hotel on a flight from Heathrow to Naples on 8 May 1970; secondly an idea propounded by First Officer (F/O) Schofield, who had devoted much thought to the problem.

(1) *The Foxtrot Hotel incident*

This event has been the subject of a wealth of evidence. It is enough to say at this stage that the Captain of a Trident II Foxtrot Hotel, Naples-bound from Heathrow on 8 May 1970, put in an Air Safety Report on his return as follows:

> **Height 1,000 feet. Visibility good. IAS 175 knots ..... When flap selected up after take-off the stick-shaker followed by the stick-pusher operated. Disconnected the A/P and built up the speed to 200 knots. Found that the droop had retracted and the droop lever was in the forward position. Droop lowered again and service continued to Naples. No controls warning.**

This being a Trident II, it was in fact equipped with slats rather than droops, but the incident as reported called for very extensive mechanical investigation. This was in fact carried out and no defect whatsoever was found which could have caused any interaction between flap and droop operating linkages. The baulk mechanism was serviceable.

Various experiments were tried in an effort to reproduce the effect described in the report but without success. The aircraft was returned to service and functioned normally.

This incident and its aftermath will have to be examined in detail at a later stage of this report. It is enough to say that we are satisfied that this was not a case of mechanical malfunction at all.

(2) *The Schofield theory*

After the report on Foxtrot Hotel had been published, F/O Schofield on 31 July 1970 put in the following report:

> **Take-off: droop failure**
>
> **On experiment I find that if the droop lever is moved to the down position and the flap lever is moved before the droop lever is fully down, it is possible for the droop lever to become locked on the baulk *only* and not on the normal down lock. All appears normal with both droop and flap levers in their correct positions, and it is not until the flap lever is selected up that anything untoward occurs. At this time the baulk is removed and the droop lever will return to the up position with the flap lever, the airspeed being some 50 knots below the correct speed for droop retraction.**

> Whilst I am not stating that this was the reason for the incident with G–AVFH, it is most disturbing to find this situation possible. If the droop lever is locked down before the flap lever is moved away from the up position then the situation described above should not normally occur. However I have noticed several pilots selecting droop down with the left hand while selecting flap down with the right, and it is in these circumstances that a misuse of the droop baulk may occur.
>
> Although the report has been closed, I feel that this information should be brought to the notice of pilots before the incident re-occurs in less favourable conditions.

In fact, an examination of the baulk and gate on Papa India discloses that it would not have been possible for the lever to have remained lodged behind the baulk, and consequently the theory can have no application to the present case.

However it is fair to say that the proposition was examined closely by Mr Henniker, the Principal Development Engineer (Airframe) at BEA and also by Mr Caliendi and Mr Sands of HSA.

It was discovered that F/O Schofield's theory as to droop retraction, though valid in some circumstances when the hydraulic system is depressurised, cannot apply when the aircraft is being operated and the hydraulic system is under pressure. Under pressurised conditions the movement of the droop selector to droop down will fully compress the spring-strut, but as the droop itself moves down the force in the spring will be released. By the time the droop is fully down the spring force will have been spent. There might in an isolated case be some residual force remaining, but this would not allow more than about an inch of movement of the lever at the most, which would not cause any movement of the droops themselves.

(c) *The three-way valve in the stick-pusher system*

Thanks to the Flight Data Recorders we know that the stall-recovery stick-pusher system continued to operate until it was dumped. It may therefore seem overcritical to make reference to any possible defects in the maintenance of the system. If established, however, such defects may be of some indirect importance.

There is in the stick-pusher compressed-air system a three-way valve placed in the fuselage. Of its three outlets, one leads via pressure-reducing valves to the engine-driven pumps, one to the air-reservoir and one to atmosphere. Its function is simply to provide a method of removing air from the system to facilitate maintenance work on the ground. It is rarely necessary to operate it.

In its normal operating or open position it allows air to flow from pumps to reservoir. If closed, any air will flow to atmosphere.

Thus if the valve is mispositioned in flight it may reduce the amount of air reaching the reservoir.

This valve on Papa India was found by the AIB to be one-sixth of a turn out of position. It was considered at first that this was the result of the impact. Closer investigation convinced the AIB that this was not so, and that any movement on impact would necessarily have been in the opposite direction, namely to bring the valve nearer to its proper operating position.

Calculations done by HSA indicate that if the valve was one-sixth of a turn out of position the air pressure during initial climb would have been sufficient to ensure that the warning light did not illuminate. After noise-abatement cutback however it would have been 63 psi instead of 108 psi.

If there was this reduction in pressure it would have two effects. First, the force of the stick-push would be marginally reduced. The evidence shows that the reduction would be so slight as to make no practical difference to the efficacy of the push itself. Secondly, if the pressure dropped below 75 lb psi at any time the amber warning light on the central pedestal would have illuminated. This would probably have happened when thrust was reduced at noise-abatement. The light is adjacent to the droop out of position warning light. The light was illuminated on impact, but this fact on its own is not significant because the incidence of the aircraft as it made its final descent was so great that there would in all probability have been insufficient thrust to maintain the necessary pressure whatever the state of the valve.

Against the AIB's conclusions must be set the fact that the Captain who had flown Papa India on the morning of 18 June had remarked nothing wrong. Had the valve been out of position then it is almost certain that the low pressure warning light would have illuminated at some stage of flight and certain that he would have noted and reported it if it had.

On balance we take the view that the valve was out of position at the material time. It was designed to be wire-locked and was wire-locked when it left HSA. At some stage that locking-wire had been removed at BEA and not replaced (a matter which we trust will not occur again). It may possibly have been moved to its discovered position by vibration in flight. In any event we find the AIB conclusions inescapable. We are supported in this view by the trace of tail plane movements* over the three stick-pushes. This shows that each push was marginally less powerful than its predecessors.

If the valve was out of position before take-off, the warning light would probably have illuminated during taxying.

One of the pressure-reducing valves in the system was found to be unserviceable. This had no material effect on the behaviour of system or aircraft.

* See fig 5.

Summary

(1) The stall warning and recovery devices were of good design and certainly by 1972 of acceptable reliability.

(2) The high-lift devices were efficient. In the early stages at least there was no reason to suppose that the baulks provided were insufficient.

(3) The autopilot was working satisfactorily.

(4) There is no possibility that the droop lever moved of its own accord.

(5) The three-way valve was probably one-sixth of a turn out of its proper operating position. This had no material effect on the operation of the stick-pusher, but may have caused the low pressure warning light to illuminate on power-cutback. This light from its position might conceivably have been mistaken for the droop out of position warning light.

Chapter IV. The human factors

A. THE INDUSTRIAL SCENE

There was in existence in June 1972 a long-standing dispute between BEA and BALPA about rates of pay and conditions of work. Strike action was favoured by some pilots, opposed by others. The effects of this dispute emerged at many stages. As to its merits or demerits we were fortunately not concerned. There was no doubt much to be said on either side.*

The dispute affected relations not only between management and pilots but also between pilot and pilot. It evinced itself in the following ways:

(i) The graffiti

On P3's table in Papa India after the crash there was found a series of offensive scribbles or graffiti, some of them directed at Captain Key, some of them at members of the BEA management staff. Those in charge of mustering the evidence realised early on that these graffiti might be some evidence that a dispute had actually taken place between members of the crew of Papa India whilst they were on board the aircraft prior to or during flight.

Accordingly the handwriting was subjected to expert examination in an effort to determine whether any of it was that of S/O Ticehurst or S/O Keighley. The handwriting expert came to the conclusion that in all probability neither of the co-pilots was the author of any of the writings, but that it was just possible that S/O Ticehurst was responsible for one of them. All the evidence shows that S/O Ticehurst's views about the threatened strike coincided with those of Captain Key, and that being the case it seems to us as certain as anything can be that the graffiti were not the product of anyone aboard Papa India on 18 June.

This conclusion was strengthened by other matters:

(a) The graffito most closely resembling the handwriting of S/O Ticehurst was by its position almost certainly not the last to be written.

(b) On 6 June 1972 F/O Spain flew as co-pilot on Papa India with Captain Key in command. Many of the graffiti were then already present on the table. Whilst on the ground preparing for flight Mr Spain said to P2 'Look at this lot!' and at that moment Captain Key appeared and asked 'What's that?' Mr Spain put his flight log over the writing and passed the matter over with some non-committal remark. He did not think that Captain Key saw the writing. Nor did he believe that it would have provoked more than an acid comment if he had.

* BALPA in these special circumstances were given leave to be represented at the Inquiry.

(c) An inspection of other Trident aircraft after the crash revealed further offensive inscriptions on the P3 tables.

Thus, what at first sight appeared to be a sinister fact, namely that on P3's table in an aircraft with Captain Key in command were found offensive remarks directed at Captain Key, turns out to be no more than an exercise in puerility which could have been found repeated in a number of other places and aircraft. The graffiti are no basis for even suspecting that there was any dissension on the flight deck of Papa India on this occasion. It is just possible that had he seen them on this occasion Captain Key might have felt some twinge of annoyance, but if he did see them it must have been before Mr Coleman came on board to discuss the load, and he observed nothing untoward about the Captain or crew.

The most one can say about the matter is that these graffiti demonstrate a regrettable attitude on the part of some pilots. They reflect no discredit on Captain Key or his crew.

(ii) The crew-room incident

About an hour and a half before the departure of Papa India, Captain Key was in the crew-room. Also there was a large number of other pilots, amongst them F/O Flavell. It seems that Captain Key, who was, as will already have been gathered, opposed to pilots taking strike action in support of their claim for higher salaries, had been enlisting the support of some of his fellow Senior Captains. F/O Flavell asked Captain Key how these efforts were progressing. This question provoked an outburst from Captain Key, who told F/O Flavell that the matter was just as confidential as the BALPA ballot. This outburst was described by at least one eye-witness as the most violent argument he had ever heard, although it seems to have been less of an argument than a one-sided expression of views. Whichever it was, although Captain Key was plainly very angry indeed, it subsided as quickly as it had erupted and the Captain took F/O Flavell by the arm and apologised for what he had said. Thereafter he seemed to outward appearances to be his normal self. Suggestions were made by Mr Kreindler in argument that this outburst provided evidence that Captain Key was psychologically unfit to fly, and that some unspecified method should have been provided to ensure that he did not. Both suggestions are untenable.

S/O Keighley was a witness to this incident. We do not know what effect it had on him, but it was certainly not beneficial. It is not known whether S/O Ticehurst was in the crew-room at the time.

(iii) P2 only

When we come to consider in detail the system for training young pilots it will be seen that after all the earlier stages have been completed to the satisfaction of the licensing authority, a further course of line training takes place. The trainee P2 has to complete satisfactorily a number of sectors under the eye of the Training Captain.

In normal circumstances the trainee would also complete his P3 training on the line before being finally allowed to fly unsupervised. This P3 line training is carried out with a Training Captain in command as P1, an experienced co-pilot as P2, the trainee sitting in the P3 seat and a Supervisory First Officer (SFO) as P4. At the time in question some 22 SFOs as part of the industrial dispute had declined to render these particular services and accordingly there were 36 pilots, who, although fully qualified as P2, had not been able to qualify as P3. We were told that such a situation had arisen on rare occasions previously. S/O Keighley was one of the 36. He had in fact completed the following P3 training: 16 hours 25 minutes on the simulator; 6 hours 45 minutes Base Training and one sector of Line Training.

This action by the SFOs was a source of some embarrassment to BEA, as no doubt it was intended to be. BEA evaded the difficulty by rostering the pilots in question to fly as 'P2 only'. This had the following effects:

(a) The usual practice whereby P2 and P3 would change places for the return journey could not be followed. P3 who by virtue of the 'brown-line' system* would be a man of some experience might, it seems, be somewhat disgruntled at not having his turn as P2.

(b) The Captain was inhibited from exercising his overriding right to place his crew as he thought best. P2, the least experienced of the co-pilots would of necessity have to act as P2. So far as this point is concerned we had evidence that many Captains might in any event choose to station the more experienced co-pilot as P3 for a variety of sound reasons.

(iv) The Dublin incident

This was a direct result of the 'P2 only' difficulty. On 15 June 1972, Captain Hagyard was rostered to fly with one co-pilot who was trained P2/P3 and one who was P2 only. He was scheduled to fly first to Dublin and return and then Heathrow to Nicosia. Although the meteorological reports were favourable for Nicosia and for the alternative, Tel Aviv, Captain Hagyard was sensitive to the ever-present possibility of rapid deterioration of conditions at Nicosia, and the fact that landing facilities there, although adequate, are not as good as at some airfields. As a result he took the view that given a choice he would prefer to have the more experienced co-pilot in P2's seat. This was not possible, because the less experienced was not qualified to act as P3. He therefore went to see the Crew Controller, who refused to give him a replacement, and then Captain Grey, the Assistant Flight Manager, who took the same view as the Crew Controller and said in effect that it was the Captain's duty to fly as rostered and that if he did not do so he would be in breach of his contract.

It is plain that the Assistant Flight Manager took the view, understandably but perhaps wrongly, that this was simply another move in the industrial battle.

* See Chapter IV C(iii).

Captain Hagyard, upset by the ultimatum, returned to the crew-room and spoke to the P2 in question in terms which he certainly would not in normal circumstances have used, suggesting that P2 would be useless in an emergency and so on. Although there was no intention to hurt the young man, and indeed the Captain has no recollection of having said anything offensive, there is no doubt that the P2 was very upset, and that his confidence was damaged.

So much so that at noise-abatement time, en route for Dublin, instead of putting the flaps up P2 selected them fully down. P3 immediately saw what was happening and reversed the movement. The flaps themselves had not had time to travel any significant distance from their previous position.

In fact Captain Hagyard took the same crew to Nicosia and that and the return journey were accomplished without difficulty.

It so happened that the P2 in that incident shared a house with S/O Keighley and told him what had happened. They met each other in the crew-room on 18 June when S/O Keighley said he was flying with Captain Key and enquired what he was like to fly with. His friend did not know.

The Dublin incident was just the sort of story which would travel quickly round the crew-room and no doubt Captain Key and S/O Ticehurst were aware of its details.

(v) Form 1179

This type-rating test form was issued by the Department of Trade and Industry (DTI). Its full title is 'Application for the inclusion of the Trident in the aircraft rating of a pilot's licence (flying machines)'.

It contains details of a number of type-rating exercises and tests which a pilot has to complete satisfactorily before he can be given his Group 1 rating on his professional pilot's licence. When the applicant has satisfied the examiner on each part, the examiner signs that part.

In early 1972 Part III c(x) had to be carried out in the air. The item was 'demonstrating in flight on a Trident aircraft his practical knowledge and ability to carry out at the systems panel of that aircraft all normal Ground Handling and in Flight procedures'.

Owing to the industrial trouble BEA were having difficulty in keeping their training programme going. One of the major stumbling blocks was the requirement that exercise (x) should be done in the air. The men who would normally have helped to carry out the exercises in the air declined to make themselves available. Captain Holdstock, BEA's Flight Manager (Training) therefore spoke on the telephone in February 1972 to the head of the licensing branch (TL4) at the DTI. This was a Mr Perry. They had a discussion about exercise (x) and the impression received by Captain Holdstock was that Mr Perry gave his authorisation for that exercise to be done on the simulator rather than on the aircraft. There is no doubt that it is an exercise which can be as well if not better performed on the simulator.

Having as he supposed got that permission Captain Holdstock on 10 February 1972 issued a notice to training captains as follows:

> Agreement has now been given by the Department of Trade and Industry for all the Part III exercises of the Trident to be cleared on the simulator and Base Training Captains should additionally sign this section when completing final checks on simulator conversion courses.

The Forms 1179 were altered in manuscript to show that the exercise had been done on the simulator and when completed they were sent to the DTI with that clear alteration upon the face of them.

In due course the DTI, albeit another branch (TL5), apparently satisfied with the 1179s, sent appropriate type-ratings to the pilots concerned. There were about 34 of them of whom S/O Keighley was one.

Mr Perry's recollection of the conversation differed from that of Captain Holdstock. He remembered discussing exercise (x) and the question of carrying it out on the simulator. He remembered accepting the idea as being a reasonable one, but believed that he would not have given permission over the telephone. He would have told Captain Holdstock to send a request in writing for the Department's consideration. No letters in fact passed between BEA and DTI on this subject.

We find it impossible to believe that Captain Holdstock would have issued the notice he did unless he had been given permission as he says. It is clear to us that Mr Perry did in fact give permission although he firmly and perfectly honestly believes now that such permission was subject to an application in writing being received.

In any event the type-ratings were duly issued by the DTI and we do not consider that, even if there were a breach of procedure in the form of test, it was such as to invalidate the type-rating in all the circumstances.

(vi) Peripheral effects

The industrial feeling produced two further peripheral difficulties. The first was that pilots showed a reluctance to take advantage of the method whereby reports of incidents could be made confidentially and anonymously. The second was that the management was reluctant to take any measure by way of investigation or reprimand which might have the effect of worsening the situation. Further reference to this is made in Chapter IV D.

B. MEDICAL

(i) Captain Key

(a) What was Captain Key's physical condition?

(b) What was the likely effect of this condition upon Captain Key's actions?

(c) Should that condition have been discovered by the medical examinations before the accident?

(d) Were these medical examinations adequate?

(ii) Pilot incapacitation.

(i) Captain Key

(a) *What was Captain Key's physical condition?*

The fact that there was no fire on impact enabled detailed autopsies to be carried out on the bodies of those who had been on the flight deck. There was no trace of alcohol or other drug. The autopsies demonstrated nothing abnormal in the case of S/O Keighley, S/O Ticehurst or Captain Collins. It was otherwise with Captain Key. The condition of his heart was abnormal. Although there was no sign of any damage to the myocardium (that is to say no scarring of the heart muscle due to earlier coronary incidents), the three coronary arteries each showed throughout their length severe atherosclerosis. This is a narrowing of the lumen (or bore) by reason of the deposit of fibrous or fatty tissues on the walls. It was a long-standing condition which must have been developing for 30 years or more. By the time of death it had reached a point where, in places at least, the effective diameter of the lumen had been reduced by 50 per cent to 70 per cent. This was a serious condition which sharply diminished his normal expectation of life. In addition to this abnormal generalised condition there were two points of more specific damage, discovered in close proximity to each other in the left coronary artery. The first was an area of localised calcification, fibrin deposition and aggregation of foamy phagocytes. This indicated that there had in the past been a cardiac incident, which had been resolved by the process of nature. It may have been symptomless.

In the same area of this artery there was also discovered a tear of the intima (that is the lining of the arterial wall). What had happened in effect was that a section of the pathologically thickened wall of the artery had become partially detached so that it was lying in the already diminished lumen but still leaving the lumen adequate for the flow of blood.

For reasons explained by Group Captain Mason, which convinced all the medical experts and ourselves, it was as certain as anything can be that the intimal tear preceded and was not caused by the impact. The cause of the tear was probably this. As the thickening of the arterial lining takes place, so small blood vessels form in the new tissue. In the nature of things, since this is unhealthy development, these blood vessels are not robust. Should there be any sharp rise in the pressure of the blood passing through the vessels, they would be apt to rupture and the resulting haemorrhage in its turn could, by creating its own pressure, force part of the intima to separate. The free blood which had resulted from the haemorrhage suffered by Captain Key is clearly demonstrated in the enlarged photographs of the sections. It was possible for the pathologists to tell from the colour and composition of that blood that bleeding had started not more than two hours before death and not less than about a minute. Precise timing must be difficult because it is obviously rare for a person to suffer from a cardiac incident such as this and then to die shortly afterwards from extraneous causes. Experience is therefore limited. The team of pathologists carried out their work with such expertise and the results were presented with such clarity by Group Captain Mason that their conclusions were in the main not in dispute.

Turning from the pathological to the physiological considerations, the next question was, what was the likely cause of the rise in blood pressure and consequent haemorrhage? It is common knowledge that any form of stress, whether physical or emotional, is likely to produce such an effect. There was on 18 June unfortunately no shortage of events which might have had such an effect upon Captain Key. On the more trivial level was the rostering as stand-by crew on a Sunday. Days of the week are all much the same to an airline pilot, but it appears from a letter which he wrote that Captain Key did set some store on spending Sundays at home. There were other possible irritations of a minor nature, namely the graffiti in the aircraft (if he saw them) and the unexpected and no doubt irritating delay before push-back caused by the necessity to alter the load. The one incident which stands out, however, as being the obvious likely cause, is the altercation in the crew room. It is clear that Captain Key was very angry indeed, though his anger was short-lived. Since this event took place about an hour and a half before take-off it is not unreasonable to suppose that it may have been the cause of the initial rise in blood pressure which resulted in the rupture of the small blood vessels.

The process thereafter would be gradual but dynamic, culminating in the separation of the intima, at a time which medically at least, can only be the subject of surmise, but may have been in the last 30 seconds of life.

(b) *What was the likely effect of this condition upon Captain Key?*

This was the subject of lengthy debate. Dr Gertler, an eminent cardiologist from the United States, was firmly of the view that anyone suffering from these cardiac abnormalities would probably collapse and become unconscious within a short space of time. He based this conclusion on the belief that the intimal tear would set up a state of arrhythmia in the heart, which would rapidly cease thereafter to operate as a pump. The brain would accordingly be deprived of the blood and oxygen required for consciousness. Dr Somerville, an equally eminent cardiologist on this side of the Atlantic, did not dissent from the view that Dr Gertler's conclusions might be correct, but he and all the other medical men we heard on this aspect considered that it was impossible to say with any certainty what the effect of this undoubted lesion might be. It might, they said, have been anything from a slight pain akin to indigestion at one end to nigh death at the other. There was no dispute that some disturbance of thought processes was likely.

We were not convinced by Dr Gertler's arguments.

Despite the fact that the torn section of intimal wall lay in the lumen, there was nothing even approaching a total blockage of blood flow and we find it difficult to see how gross arrhythmia can on the evidence be anything but a mere possibility and a slender one at that.

Taking the circumstantial evidence into account together with the medical, we believe that Captain Key was throughout take-off and initial climb, distracted by some degree of pain and discomfort, that the pain was increasing as time went on and that the stage was reached where his powers of reasoning were materially affected. We doubt whether this was noticed by the others on the flight deck.

(c) *Could this condition have been detected by the medical examinations undergone by Captain Key?*

Captain Key presented to those who knew him a picture of robust good health. His wife had no idea that he might be suffering from any sort of disability. He was an enthusiastic and active gardener. Dr Salmon, his family doctor, had no suspicion that anything was wrong. Captain Key had consulted him on a few occasions, but these were only upon trivial matters, and unconnected with any cardiac symptoms. Dr Preston, one of the doctors at the BOAC/BEA joint medical centre at Heathrow also knew Captain Key well and regarded him as being in good health. The only matters of any import upon which Captain Key had visited the centre were his worry and concern about his failure for a time to achieve the position of route check captain. This was depressing him and he had been told by one of the doctors at the centre, Dr Barnes, in 1970, that he should sort out the trouble one way or the other, or forget it, otherwise he might have to be taken off flying. Here again, though casting some light on his personality, these matters are irrelevant to the heart condition.

There was put before us a body of correspondence passing between Captain Key and BEA. In a letter dated 13 February 1972 Captain Key related how he had felt himself obliged to fly on one occasion though he 'had not been feeling too well for the previous two days' and that he had been 'prepared to take a chance'. As it happened, there was independent evidence available to us that on the date in question Captain Key did not appear to be suffering from ill-health, and it seems that the letter in question may have been an example of the liking for hyperbole which emerges from his letters. It is certainly no evidence that he was aware of his state of health either in general or on 18 June before he took off.

Our attention was also drawn to errors which Captain Key had made in completing the last page of his log book. Certain entries had been put in inappropriate columns. We do not regard this as being of any material significance.

Medical examinations apart, there was no reason for anyone to suspect that his heart was anything but normal.

Should, then, the diseased state of the coronary arteries have been detected in medical examination? This was one of the areas in the Inquiry where there was a sharp clash of evidence. There were two relevant medical examinations undergone by Captain Key, one in November 1970 and one in November 1971. It was not suggested that any simple clinical examination on either occasion would have revealed the condition, but Dr Gertler considered the electro-cardiograms of November 1970 and 1971 demonstrated clearly an abnormal heart condition meriting at the least further investigation. Dr Somerville, however, would have passed both cardiograms as normal.

In these circumstances the immediate result must be that the doctor who passed Captain Key fit to fly can in no way be criticised. Had that doctor wanted a second opinion and had he passed the cardiograms to Dr Somerville, as one of the leading experts in the country on the problem, his view would have been confirmed.

We do not however feel that the matter should be decided solely on that short point.

Dr Gertler based his opinion on what he contended was an abnormal 'left axis deviation' demonstrated on the 1971 ECG. In order to understand this, one must understand the rationale which lies behind electro-cardiograms. In lay terms this is as follows.

The heart-beat is controlled by a series of minute electrical impulses which travel across conductive material surrounding the heart. By placing electrodes in various predetermined positions on the patient's body (namely, chest, arms and legs) it is possible to ascertain within broad limits whether the electrical impulses are behaving normally or abnormally. One indication of abnormality is if there is a deviation in what is called the left axis of more than minus 20^{o}. Dr Gertler told us that the 1971 ECG demonstrated a left axis deviation of no less than minus 49^{o}, which put it into the abnormal range. Such a reading would demand further close investigation of the patient. Dr Gertler at one point in his evidence went further than this. He said that the 1971 ECG compared with that of 1970 'told me beyond reasonable doubt – as a matter of fact I was 100 per cent sure – that this person has disease in the left anterior bundle, known as the left anterior hemi-block, technically'. One of the criteria for a left anterior hemi-block is stated by Dr Brigden in his treatise on the subject to be 'a left axis deviation (usually minus 60^{o})' and so the diagnosis of a hemi-block does not seem to be supported by Dr Gertler's own reading of minus 49^{o}.

However, if minus 49^{o} was the correct reading, it was still abnormal.

Dr James, who was responsible for reading the ECG in the first place, had passed it as normal and Dr Somerville gave evidence to us that the deviation was only about minus 8^{o}, that is well within normal limits.

This huge discrepancy between expert cardiologists was startling. Accordingly we asked Dr Somerville to explain to us the method by which the angle of deviation is measured. He did so, and thereby made it clear that Dr Gertler was mistaken, as Dr Gertler had himself largely conceded. This view was confirmed by Dr Brigden. Captain Key's ECG was manifestly normal. This is not as surprising as it may seem. The type of ECG carried out will usually demonstrate a myocardial infarct, but rarely if ever arterial atheroma.

(d) *Were the medical examinations adequate?*

Here again there was a lively difference of opinion between the medical men.

The importance of adopting the most efficacious test possible for abnormal heart condition can hardly be over-emphasised. Although BEA had up to now suffered no accident due to pilot-incapacity, the incidence of abnormal coronary conditions in apparently healthy people is more common than one would suspect. Studies carried out on both sides of the Atlantic have shown that no less than some 19 per cent of apparently fit young airmen may be suffering from some degree of coronary arteriosclerosis.

Dr Gertler is an enthusiastic proponent of the 'stress test' school of cardiologists. Their belief is that the 'resting' cardiogram is not adequate. They believe that maximal or sustained stress testing ECGs will detect coronary heart disease (such as that suffered by Captain Key) in apparently healthy individuals. The way in which these tests are carried out is (in lay terms) to make the patient take some form of violent exercise, whilst monitoring the heart to avoid the danger of over-stress, and then to take the necessary readings.

Dr Somerville took the view that this method is of little value, because the number of false negatives and false positives was likely to be too high. On the one hand, he thought, many people with abnormal coronary arteries would be passed as fit, whilst many perfectly healthy individuals would be condemned as potential cardiac casualties. That conclusion was largely based on a 9-year follow-up report published in 1963. Dr Gertler argued that that report was out of date and has been overtaken by events.

However no evidence was forthcoming before us that the stress tests were any more reliable now than in the past except that one or two American airlines had introduced them as standard practice.

No country yet insists upon stress testing for airline pilots. We are left with the impression that in the near future stress testing may be sufficiently accurate and reliable to be adopted as standard procedure, but that at present it is not.*

It is a matter which must be kept under urgent review.

Certainly no one can be criticised for not having introduced it by November 1971 when Captain Key was last tested.

* This was broadly the conclusion reached at the International Civil Aviation Organisation Conference held in Montreal in 1970.

We should perhaps add that arteriosclerosis can be detected by means of an arteriogram, but the dangers involved in the procedure are too great to allow its use for a routine medical examination.

(ii) Pilot incapacitation

The importance of guarding against accidents caused by physical incapacitation of the pilot need hardly be stressed.

The causes of incapacitation are not confined to abnormal heart conditions, although they may produce the most dramatic results. Degrees of incapacitation are infinitely variable. Indeed the total and obvious collapse of the handling pilot is probably easier to deal with than the subtle incapacitation which may go unnoticed for a dangerously long period of time.

Routine medical examinations will never be able to eliminate the danger of incapacity during flight. The pilot himself is enjoined by the terms of the *Air Navigation Order* not to fly if 'he has reason to believe that his physical condition renders him temporarily. . . . . unfit to perform such function'. But inevitably occasions will arise when the malaise seems so slight to the pilot as not to warrant a refusal to fly, or where he is suddenly and without warning attacked by illness in the air. Even if the result is a subtle incapacity involving slow reaction and impairment of judgment, there is no reason why the aircraft should be endangered. If the monitoring system is working as it should, any serious falling-off in performance by the handling pilot should be picked up by the other crew members. In the *Aerospace Magazine* June 1972 edition appears the following passage from an article by Captain R C Leighton-White who is himself an airline captain.

> In the absence of any obvious indication of incapacity, it is only by a continuous critical monitoring of a pilot's actions that his incapacitation may be detected at an early stage. This requires that all crew members closely monitor the aircraft's flight in the critical stages of take-off, initial climb, final approach and landing and *immediately* question any deviation from the norm. Crew procedure should include this as standard practice. It is also implicit in this requirement that to critically monitor and question a captain's actions, the co-pilot must have sufficient training and experience to have the necessary confidence in his own judgment to question a senior pilot's action.*

With those views we agree.

In the September 1971 issue of the same publication appear the results of tests carried out in a simulator to discover the likely reaction by the other crew members to the subtle incapacity of the captain.† In the first 18 tests the crew were not warned of what might happen. The captain ceased functioning somewhere during the landing approach. Twenty five per cent of these tests ended in a 'crash'. Of the remaining 75 per cent the range of time before detection of the captain's condition was 30 seconds to 4 minutes, with a mean of 1.5 minutes. The second 18 tests were preceded by a short briefing session and a discussion of the possibility that if the handling pilot did not respond after a significant deviation from a standard flight profile, the other crew members should be alert to the possibility of a subtle loss of function. There were no 'crashes' in any of these 18 tests. In each the co-pilot took over safely.

* This article was written before the accident to Papa India.

† The authors of the article were C R Harper, G J Kidea and J F Cullen of the Medical Department of United Airlines.

C. TRAINING AND THE CREW

(i) Training the young entrant

Most of the young pilots in BEA come from one of the Colleges of Air Training at Hamble or Oxford. S/O Keighley had been trained at Hamble. This college demands a high level of academic qualification from any would-be entrant.

During the course there is an examination for the Commercial Pilot's Licence and a further flying test for the Instrument Rating, and the student has to prove his proficiency in a variety of aviation subjects. Practical skill in the air must also be demonstrated by a general flying test in four parts. For the Instrument Rating the candidate must pass tests (inter alia) in planning an instrument flight for a public transport operation in controlled airspace, and in flying correct aircraft procedures including a holding procedure; carry out a descent and approach to land using Instrument Landing System (ILS) followed by an overshoot from critical height; and carry out descent approach using either Non-Directional Beacon (NDB), Very High Frequency Direction Finding (VDF) or Visual Omni-Range (VOR). Students take the type-rating test for at least one of the types flown at the school.

The minimum number of flying hours at Hamble will be 225. Thus on arrival at BEA the young pilot has a certain amount of flying experience and technical knowledge as well as his Commercial Pilot's Licence, instrument and type-rating. Hamble demands the best and BEA have come to respect the quality of its product. They have taken about 770 pilots from there during the last 10 years. Several foreign airlines also put their young entrants through the college.

On arrival at BEA the pilot has to undergo four further training stages before he is permitted to act unsupervised as co-pilot of a Trident.

(a) Ground school at the Heston training centre for some 6 weeks. This involves instruction on the operation, construction and systems of the Trident. There is a CAA examination at the end.

(b) A flight simulator course also at Heston lasting approximately 3 weeks. This involves some 54 hours in the simulator to familiarise the pilot with the normal, abnormal and emergency handling procedures. The exercises to be done are set out in the *Training Manual.* This syllabus is approved by the CAA. Exercises at the time S/O Keighley did his training included stall recovery procedures, which were carried out on the simulator as items 208(a), (b) and (c) of the simulator course.

On item 208(a), the final approach configuration was adopted, throttles closed, trim about 140 knots and the control column gradually eased back until first the stick-shaker and then the stick-pusher appeared. The trainee was then taught how to fly out of this situation.

208(b) is a similar exercise but with power set to about 11,000 rpm.

208(c) is again similar but this time carried out in turning flight.

It is illuminating in this context to see BEA's *Notes to Training Captains,* p 8

> . . . The stick-shaker will then come on and the reduction of speed is then continued. As the Max Cl is approached the nose will come up on its own with only a very light pull. As this could be dangerous to a pilot who applied a constant rearward force on the control column a stick-pusher is fitted. This always operates after the stall warning and puts the control column as far forward as it is possible to move it . . .

Later

> . . . The stick-pusher is affected by a rate gyro which will cause it to operate sooner than on 'lg' stall, but it can never operate before the stick-shaker warning.

Thus, not only was there no suggestion that there might be an almost simultaneous stick-shake and push, but the inference was that there would *always* be an adequate warning before the push.

Further exercises were carried out on malfunction of the stall warning and recovery systems.

Owing to the dates at which each had received his training the three pilots had had different forms of instruction on the stall. Captain Key had had the opportunity of himself flying the aircraft to the stick-push and of flying the recovery. S/O Ticehurst had complete flight handling instruction in stalling on the simulator. This was repeated on the aircraft with recovery from the stall warning only. S/O Keighley had done all his stall training on the simulator. Proper action to be taken in the event of speed loss was also taught; this included not only the duties of P2 in these circumstances but also the monitoring duties of P3.

Prior to 18 June 1972 there was no demonstration of the effect of premature droop retraction and there was no exercise demonstrating the possibility of a stall warning at climbing attitudes, although the pilot's attention was drawn to the increased dangers of stalling in turning flight. We were told that there is at present no airline in the world which gives instruction on the change of configuration stall.

There were also exercises in the syllabus which cover the possibility of the Captain becoming incapacitated during flight. (Section 13 of the *Manual* Item 1436 page 18.) This was by way of lecture rather than practical demonstration and was confined to obvious incapacity and collapse of a crew member. S/O Ticehurst did not have this instruction. The *Flight Manual* Instructions are also confined to obvious collapse.*

* See Appendix E.

At the end of the simulator stage there is a further test (Form 1179 Part III A (i)-(iv) incl). The examiner here is a BEA Base Training Captain authorised by the CAA.

By this time the pilot will have himself experienced both stick-shaker and stick-pusher on a number of occasions and will have seen it operate in the hands of fellow-pilots on many other occasions.

(c) The third stage is the Base Training Course lasting about 10 days. This provides the trainee with the opportunity to familiarise himself with the technicalities of the aircraft itself. He carries out day and night take-offs and landings including practice in engine-out situations. By the end of the course what remains of the Type-Rating Test is completed. The previous simulator training is filled out by practising certain manoeuvres in the air.

(d) In addition the pilot must be checked to the required standard on line operations. This demands that he should fly on the line with a Line Training Captain as P1. The minimum number of sectors to be so flown is 16. In fact he will probably fly about 30 before he is passed as suitable.

There is a recurrent checking procedure. Once every 6 months the pilot has to undergo a competency check. There is a route check every 12 months starting 6 months after the completion of training and an instrument rating renewal check once a year.

The system of training is well devised and, from what we have seen, carried out with great care and thoroughness. So long as it could safely be assumed that no pilot was likely to retract the droops at an abnormally low speed, the training on the stall warning and recovery system was adequate. If such untimely retraction was a reasonable possibility the training in that respect was insufficient if not misleading.

(ii) Monitoring system

BEA like other airlines have long been aware of the fact that however carefully a pilot is trained and disciplined and however experienced he may be, the possibility of his committing some error can never be disregarded. It was with this realisation in mind that BEA introduced their 'monitored approach system', with the object of giving increased safety to what may be the most critical period of flight, the let-down, approach and landing. The system was, in brief, that the task of approach and landing should be divided between P1 and P2 so that one pilot handled the let-down and remained firmly on instruments while the other carried out the landing as soon as he had adequate visual reference. If visual reference was not achieved at decision height, the pilot on instruments was in a position to control the aircraft with the minimum of uncertainty. If the Captain was satisfied that he had full visual reference he would then carry on to do the actual landing. Meanwhile P3 was in a position to monitor the actions of each of his colleagues.

From these beginnings developed the idea that all the critical stages of flight should be the subject of monitoring. Flight decks were laid out in such a way as to ensure so far as possible that P3, as well as P1 and P2, could carry out most of his tasks in the forward-facing position.

With P1 handling on the initial climb, P2, apart from the duty of raising flaps and reducing power at the appropriate moment, is free to monitor the flight instruments and P1's actions, and P3 from his position has the duty to 'continue to monitor the flight instruments, select frequency changes as requested by ATC and advise the Captain'.

Thus if on the accident flight the monitoring system had worked as it should, the great speed errors would have been noted both by P2 and by P3. S/O Ticehurst should, as one witness put it, have been almost literally screaming 'Speed!' at the Captain.

Whoever it was who moved the droop lever, the other two, and certainly S/O Ticehurst, should have observed the movement.

The idea behind the monitoring system is excellent. Whether sufficient emphasis is placed on the necessity for continual alertness throughout the initial climb is questionable.

The deeper problem of whether the three-pilot system is in fact the best that can be devised was not debated and accordingly we express no views.

(iii) The 'brown-line' system

BEA are conscious of the desirability of maintaining a balanced level of experience on the flight deck. They therefore instituted a method known as the 'brown-line system' to ensure that where one co-pilot had less than 12 months on the type he would always be rostered with a co-pilot who had had more. The under-12 months pilots had a brown line drawn under their names to distinguish them.

Since the accident BEA have altered this system so as to require a co-pilot of at least 2 years experience on the type to be rostered with a brown-line pilot.

(iv) The crew

Each of the three members of the Flight Crew held a Professional Pilot's Licence endorsed for the Trident I and II. Captain Key held an Airline Transport Pilot's Licence and S/Os Ticehurst and Keighley each held a Commercial Pilot's Licence with instrument rating. All tests and examinations necessary to maintain the licences had been carried out and the licences were valid at the time of the accident.* It is worth remarking that Captain Collins was himself an experienced Trident pilot.

During the 28 days prior to the accident Captain Key had flown 51:35 hours, S/O Ticehurst 54:25 and S/O Keighley 33:35 hours, all in Trident aircraft. Their duty periods during the seven days before the accident were well within the legal limits.

* See Chapter IV A where the dispute as to the validity of S/O Keighley's type rating is discussed.

No question of fatigue arises in this case.

Captain Key was 51 years of age. He had a total of some 15,000 hours as P1 and P2 with 4,000 as P1 on Tridents. He was a Route Check Captain and a man who had a reputation for observing standard procedures. There is no reason whatsoever to doubt his reliability, experience or skill.

S/O Ticehurst was 24. His total flying hours as P1 and P2 were over 1,400. On Tridents he had flown over 750 hours. He was a competent and conscientious pilot.

S/O Keighley was 22. He had only been flying on the line for a short time. He was one of those young co-pilots who had been affected by the 'P2 only' situation* and also by the trouble over the Forms 1179. These matters, coupled with the suggestion that it was he who moved the droop lever, led to a minute examination of his training records and of the reports made on him by his various instructors. For such reports to be of any value they must be frank and outspoken and they must stress such deficiencies as there are. It should also be remembered that where comparisons are made, the standard is not that of the average young man of 22 but of the very high quality of trainee pilots emanating from the training school.

As his reports from Hamble showed, S/O Keighley was slow to learn and somewhat under-confident. Much to his credit, he succeeded by sheer determination in overcoming these handicaps sufficiently to pass the course. 'He will need' ended one report, 'careful watching'. It was clear that here was a young man who in the end would make a solid, reliable pilot, but for whom the progress to that end was going to be difficult. It was pointed out by more than one instructor that stress might cause him difficulties.

Much the same pattern appears in the reports from the simulator course at Heston and his base training at Prestwick. Mr Roberts, the simulator instructor, and a man of obvious sensitivity, reporting on 15 March 1972 said this: 'Although his skill in handling was satisfactory and the memory items of the Emergency Drill were correctly carried out, he was slow to react to an emergency . . . . . he lacked initiative'. He gradually improved as the simulator course progressed. At the end of it the instructor was satisfied that this improvement would be maintained and that he would make a good reliable pilot, but thought that longer than usual would be needed over both P3 and line training. As it happened, his line training was completed within the normal time. It is interesting to note that he dealt satisfactorily with one real emergency during his line training.

On the simulator he completed 18 hours as P1, 17 hours as P2 and 16 hours as P3.

His base training comprised 10 hours as P2, 7 hours as P3 and 2 hours as observer. Here he was found to be rather slower to react than the average.

* See Chapter IV A(iii)

On line training he showed consistent improvement in his skills, though requiring the occasional prompt 'to get ahead of the aircraft', and his monitoring was good. The handing-over report on 2 May 1972 reported him as 'slower than average and will call for patient, rather than pressure, handling'. He flew 29 hours (involving 17 sectors) as P2 before the accident.

One is left with the impression of a thoroughly likeable, unassuming young man, desperately keen to succeed in his chosen profession, who undoubtedly would have so succeeded had the fates been kinder.

It was the worst of bad luck that he should have been in the P2 seat on this occasion. His witnessing of the crew-room incident between Captain Key and F/O Flavell can have done nothing but harm to his self-confidence. It may well have given him an alarming impression of the Captain with whom he was about to fly. His natural tendency towards self-effacement would not have encouraged him to question the actions of his Captain without serious deliberation, particularly a Captain with whom he had never flown before, and his slower than average reactions would probably not have been a match for the sudden and alarming events on the flight deck. It would be a harsh judge who would criticise S/O Keighley for anything he did or failed to do in these circumstances.

(v) A question of experience

Despite the brown-line system a great deal of criticism was levelled at the BEA policy of allowing young pilots to act as P2 on the line when their total flying hours are only about 250 and their experience on the type may be limited to some 13 hours handling the simulator and about 10 hours actually in the air. Two sharply divergent points of view emerged.

Some line pilots (the Dublin incident was an example) took the view that the young co-pilot was allowed to act as P2 with far too little experience for safety. Dark forebodings were expressed. This view was supported in a letter placed before us signed by 44 BEA Captains and addressed to the Chairman of the CAA.

The contrary view was expressed amongst others by Captain Lowden, Captain Poole and Captain Owens, who stated that the standard of the young men is basically high, their elementary flying training is good, their training on type is more than adequate and they are in short well-trained, reliable and keen.

It is not without significance that apart from the Dublin incident (which was a special case) the really dangerous occurrences of which we have been told had not been due to the actions of either of the co-pilots; secondly the co-pilots we have seen and heard whether in the witness box or at Heston or Heathrow have greatly impressed us. Certainly the adverse publicity about co-pilots' skills which this Inquiry has engendered is unjustified.

There can be no valid criticism of the technical capabilities of the young P2s. They are well trained in basic airmanship and in the day-to-day handling of the Trident and its systems.

Co-pilots are provided for these main reasons: to take some of the workload from the Captain's shoulders, the certifying authority deeming rightly that the complexity of the aircraft demands more than one pilot; to guard against the possibility of the Captain becoming incapacitated; to act as a monitor. The last two are closely connected (see Chapter IV B(ii)).

The standard of training is more than adequate to satisfy the first of these requirements. S/O Keighley for example was perfectly capable of carrying out the routine tasks which were his share of the workload, of flying the aircraft if called upon to do so and of handling most types of emergency. The more difficult question is whether the experience gained by these entrants, as opposed to their training, is sufficient before they start to fly as P2 on the line to enable them adequately to discharge their other two functions.

D. POSSIBLE FOREWARNINGS

(i) The Foxtrot Hotel incident

Brief reference has already been made to this event in connection with the possible malfunction of the droop lever mechanism. The investigation of this incident and its aftermath occupied a great deal of time. Most of the main parties were involved. What happened to Foxtrot Hotel bore in some respects a striking resemblance to what we know of the flight of Papa India, and the suggestion is that if more attention had been paid to the earlier event, the crew of Papa India might at least have been better prepared to meet the emergency which faced them.

Foxtrot Hotel being a Trident II was equipped with slats rather than droops, but the distinction is immaterial in the present context. It took off from Heathrow en route for Naples on the morning of 8 May 1970. Two members of the Flight Crew gave evidence before us. The statement of P3 was read. The Captain* described to us that he had been the handling pilot; that after take-off the autopilot was engaged and the aircraft started to climb away at 175 knots. P2 carried out the noise-abatement procedure, he said, and at about the same time they got the stick-shaker followed instantly by the stick-pusher, and then after a very short pause a further stick-shake and stick-push. The Captain's first reaction was to check his air-speed and attitude and to check that they were accelerating. He then made up his mind that it must be a false warning because, so he said, he could not see any warning lights flashing. The air-speed was building up. He could see the ground and the attitude of the aircraft, and everything seemed to be in a safe condition. He could recollect no audio warning as the autopilot disconnected. He told P3 to check the stick-shaker circuit-breakers and operate them. He then continued with the flight, everything having returned to normal. It was only, he said, after a further 5 minutes or so of the flight that P2 told him that the slat lever had been at the time of the stick-push in the forward position and that he, P2, had moved it back. Later on during the flight the Captain questioned P2 and P3 as to whether they had moved the slat lever and they denied it. The Captain said he therefore assumed that the lever must have moved forward of its own accord when the flap lever had been moved. A brief radio report, he said, was passed to Heathrow before they reached Dover. Some of the passengers noticed the effect of the stick-push and asked the Captain about it.

* He has now, we are told, reached retiring age and is no longer with BEA.

P2 told us that, according to his recollection, after the autopilot had been engaged the Captain reached across and selected a different frequency on the No 2 VHF set, presumably the noise-abatement frequency. Then he, P2, carried out the noise-abatement procedures, and just as his hand was coming away from the thrust-levers, having reduced the thrust, there was a stick-shake followed closelv bv a stick-push. Speed was 175 knots and height between 1,200 and 1,400 feet. He could see nothing wrong. Speed and attitude seemed to be correct; the aircraft was not in a severe bank. After a few seconds there was another stick-shake and push. There was an audio warning on autopilot disengagement but that was cancelled by the Captain. He could remember no other warnings and was quite sure that there was no CWS warning and no amber or red flashing lights. P3 turned round to deal with the circuit-breakers. P2 was in the act of turning in order to pull the stall-recovery override lever, assuming it to be a false operation of the system, when he noticed the slat gauge registering 'up' and immediately selected slats down again. Meanwhile, he said, the Captain was just about managing to hold the aircraft level – 'the result being', as he put it, 'that the aircraft just about managed to stay flying'.

The Captain's Air Safety Report has already been set out*. The incident was as a result of this report treated initially as one of mechanical malfunction and BEA in conjunction with HSA carried out exhaustive tests to try and discover what, if anything, had gone wrong with the system. It eventually became apparent that it had not been a mechanical malfunction at all.

The incident was reported in the *BEA Air Safety Review* of May 1970 as follows:

> Acc. 70/5467 (Take-off: droop failure)
>
> TRIDENT TWO G–AVFH Heathrow/Naples 8.5.70
> BE 326
>
> At a height of 1,000 feet when flap was selected up after take-off there was a stall warning followed by operation of the stall recovery system. IAS was 175 kt. The autopilot was then disconnected and the speed increased to 200 kt. A check on the controls showed that the droop had retracted and the droop lever was in the forward (retracted) position. It was lowered again and the flight continued without further trouble. At no time was there a droop out of position light, a controls warning or a take-off configuration warning.
>
> Following this incident, the controls, including the controls warning system, were comprehensively checked but no faults could be found. The aircraft has since flown over 140 hours with no recurrence of the defect. CLOSED.

Many details of the incident emerged at the Inquiry for the first time. No one, for instance, previously knew that the crew were on the point of operating the stall recovery override lever. No one knew that the Captain occasionally (as he admitted) operated non-standard procedures when flying out of Rome by raising his flaps very soon after take-off to obtain a better rate of climb. No one knew, as now appears probable, that this Captain was the man in command of the aircraft involved in the Orly incident described hereafter.

Even now it seems probable that we do not have the full story of what happened. For instance, it seems certain that the speed must have been about 10 knots lower than that reported for the stick-pusher to have operated as it did. The chance of there having been no 'controls' warning is about one in a million and can be discounted.

* See page 17.

We are driven to the conclusion that the reports made by the Captain were not as full or as frank as one would wish, and therein lay the beginning of the difficulties. The Voyage Report and Captain's technical report were no more explicit.

On any view these laconic reports scarcely did justice to the event as it was described to us. The mechanical side of the incident having been fully investigated by HSA and BEA only to show that nothing abnormal had occurred, it followed that the slat lever must have been moved by a member of the crew. For that to have happened the flaps must already have been moved to the 'Up' position so releasing the slat lever baulk. The likelihood is that flaps were retracted early after take-off and then the slats were retracted at noise-abatement time in mistake for the flaps.

It is not necessary to go into great detail about subsequent events. The matter was investigated by a number of people at BEA. Captain Nicholls and Captain Wallis, the Flight Manager and Assistant Flight Manager respectively of the relevant Trident Flight, apparently saw the P2, though Captain Nicholls had no recollection of this.

The Air Safety Branch took the matter up. Mr Brinjes, one of the Air Safety Officers in company with Captain Dell, the officer responsible for technical matters, interviewed the crew. He was given the impression that they had had no problems at all in controlling the aeroplane and that it had flown out into normal flight without any real difficulty. No reference was made to the fact that there had been more than one stick-push or that there had been an intention to dump the recovery system.

On 20 May 1970 Mr Brinjes asked for the Flight Data Recorder readout, but unfortunately the record had already been erased. This request was probably made as the result of a suggestion from the Captain, but the readout would not have been very helpful. The parameters recorded would have been time, attitude, heading, speed and altitude. There were no event markers for flap or slat retraction. It did not seem to Mr Brinjes that any useful purpose would be served by interviewing the crew again because they would only have continued to repeat what they had said earlier, namely that they did not move the droop lever. He considered that there was no concrete evidence of crew mishandling and that any further challenge of the crew would simply undermine such confidence as existed between the ASB and pilots. He therefore wrote the report for the *Air Safety Review* set out above and marked it 'closed'. Mr Brinjes thought that he would have completed that document towards the end of June 1970.

However, we know from the minutes that the matter was discussed at the BEA Air Safety Committee meeting of 25 June 1970 when Captain Lowden, then General Manager Flight Operations, expressed concern at the potentially dangerous situation disclosed and again at the July meeting when a decision was taken not to pursue the matter. Between then and 19 August 1970 some further information must have reached Captain Lowden, because he issued the following memorandum:

> I believe we should not be satisfied to leave this incident as closed. We must see what further training or procedural aspects could be revised to avoid a similar dangerous situation. For example, if we think that there is a possibility of incorrect procedure being followed, perhaps we could emphasise that the gauges should be checked before and after operation of the controls, as we do, for instance, when we select droop and flap for take-off.

> If we thought that there was a possibility that the droop lever was moved inadvertently, perhaps an improved locking device is required for the down position. I understand that the recovery system or the warning operated twice* which suggests that the crew did not immediately react to the warning in the correct manner. If this is so then this fact might be used in checking and training to emphasise the correct drill.
>
> I hope that when you have looked at all these possibilities you will be able to make firm recommendations. It may be that the whole investigation will have to be re-opened.

Captain Dell† and Mr Gordon Burge, head of the Air Safety Branch, were both sent copies. In fact nothing was done so far as the operational side was concerned, although the engineers were still busy. Captain Dell had other more pressing problems on his plate and in any event he took the view that in the delicate management/pilot situation it would be both unwise and unproductive to pursue the matter by any further questioning of the crew. So far as the ASB was concerned Mr Gordon Burge saw this memorandum. He took no action, though he now recognises that he should have done. Mr Brinjes has no positive recollection of it, but believes he must have seen it. He too took no action although it plainly suggested that further facts had come to light. He apparently decided not to go back to the crew for another interview. Ironically, P2 at least was expecting to be questioned further about the matter and had made notes for his own use should that happen. These notes were no longer extant at the time he gave evidence to us.

In Autumn 1971 Captain Lowden was succeeded as GMFO by Captain Owens. This particular file was one of those he inherited from Captain Lowden, and he wrote to Captain Dell asking what had been done. Captain Dell replied on 22 November 1971:

> So far as normal operating procedures were concerned, it was felt that a hazardous situation might arise if soon after take-off flaps were retracted to give a better climb performance which would then leave but one lever – the droop lever – which could be moved inadvertently at the moment of power cutback.
>
> This then reinforced the view that strict adherence to our normal procedure provided the chief safeguard, rather than introducing a further change.
>
> The main gist of the foregoing was made known to the then GMFO at the time.

On 29 November Captain Owens closed the matter.

(ii) The Orly incident

In December 1968 F/O Whitehead was P2 on a Trident bound for Heathrow from Orly. He was the handling pilot.

Very soon after the undercarriage was retracted the Captain without telling anybody moved the flaps to fully up, to get a better rate of climb. At noise-abatement time the Captain reached across and retracted the droop and reduced power to normal climb. F/O Whitehead felt the aircraft sink rapidly, but he knew the reputation of the particular Captain and was on the alert. He saw the droop gauge moving up and immediately pushed the stick forward to increase his speed to compensate for the retracted droop, as he put it. Meanwhile the Captain selected droop down again. The autopilot was not at any

* Captain Lowden was unable to remember the source of this information.

† Captain Dell was the man on the operations side charged with the responsibility for technical matters to do with Trident aircraft.

time engaged. F/O Whitehead's prompt action prevented the stall warning or recovery systems from coming into action. He was reluctant to report this incident and thereby to get the Captain into trouble. However in mid-1970 thanks to the efforts of Mr Gordon Burge a system of confidential reporting was instituted designed to overcome this type of reluctance. The notice advertising the system ran as follows:

> MOST OF US HAVE MADE A MISTAKE IN THE AIR AT SOME TIME, PROBABLY BECAUSE WE WERE OVERLOADED OR DISTRACTED. HAVING GOT AWAY WITH IT YOURSELF, DO YOU EVER FEEL THAT IT MIGHT HAPPEN TO SOMEONE ELSE WHO WILL NOT BE SO FORTUNATE?
>
> IF YOU HAVE HAD AN INCIDENT LIKE THIS AND FEEL THAT YOUR EXPERIENCE WOULD BENEFIT FELLOW PILOTS – BUT DO NOT WISH TO REPORT IT OFFICIALLY – I WOULD LIKE YOU TO TELL ONE OF THE MEMBERS OF THE GROUP LISTED BELOW.
>
> NEEDLESS TO SAY THE INFORMATION WILL BE TREATED WITH THE UTMOST CONFIDENCE.

F/O Whitehead took advantage of this scheme, and reported the events. In due course Captain Corbishley on 3 September 1970 published the following paragraph in the Trident Flight Safety Group File:

> 9. *Non-standard after take-off drill* First Officer's Report. First Officer handling. On take-off from Orly after the undercarriage was locked up the Captain raised the flap fully up to achieve a better climb out. At 75 seconds the Captain again reached across and moved the only lever there forwards reducing power to normal climb. As the *droop* had been selected up the aircraft 'dropped like a brick' until speed was increased and droop re-selected down.
>
> *Comment* – This highlights the necessity of following standard procedures.

We respected F/O Whitehead's wish not to give the name of the Captain to us, but it is tolerably clear from other evidence before us, including that of the Captain himself, that he was the man involved in the Foxtrot Hotel incident.

One would have expected the incident to be picked up by the Air Safety Branch and collated with Foxtrot Hotel, if for no other reason, because of the short time elapsing between the reports of the two incidents.

Once again misfortune dogged that organisation. Mr Brinjes, owing to some error in office procedure, never saw the file at all and was unaware of its existence until it was mentioned in the course of this Inquiry. Thus the first opportunity of connecting the incident with Foxtrot Hotel was lost. Mr Gordon Burge was at the time away from the office for a long period, and during his absence there does not seem to have been any method whereby someone else undertook his duties. It was not until late December 1970 or early January 1971 that he saw the confidential report, namely some 4 months after its publication. He did not connect it with Foxtrot Hotel. Mr Gordon Burge took the view, as he told us, that he amongst others had become mesmerised by the effectiveness of sticking to well-established procedures and instructions. He was the first to admit that over the last two years it has been becoming abundantly clear that that is not enough.

There was in existence in the ASB a cross-indexing system for the express purpose of linking-up two such incidents as these. Unfortunately, incidents reported only in the confidential file were not inserted in the cross-index. Therefore if the two incidents were to be matched, it had to be by the memory of Mr Brinjes or Mr Gordon Burge. Events conspired to prevent that.

We believe that in the Air Safety Branch BEA have an organisation with great potential for preventing accidents. It is much to their credit that they have set it up at all. Very few airlines, we were told, have a comparable system. We hope and believe that in future it will prove a much more effective weapon. It may be that the management themselves were not fully aware of how good a potential life-saver they had in the branch.

Captain Dell read the confidential report of this incident but, it seems, not until a little time after its appearance on 3 September. He did in fact link it in his mind with Foxtrot Hotel, but he thought, for reasons which were not altogether clear, that the Orly report might be a 'highly camouflaged version of the Foxtrot Hotel incident'.

The position of HSA

HSA knew nothing about the Orly incident.

We do not think that they could have been expected to do any more than in fact they did about Foxtrot Hotel. The Air Safety Report was seen by one of their service engineers resident at Heathrow and he immediately telephoned to the appropriate department at Hatfield. There an incident report was made out and circulated to all the HSA top management.

The Deputy Development Chief Engineer spoke to Mr Cope of BEA and offered any assistance that might be required on the management side. The *Flight, Operations* and *Maintenance Manuals* were all checked by the HSA Publications Department to ensure that there were no ambiguities in them, and the appropriate aerodynamic calculations were made to check whether inter alia a simultaneous stick-shake and push could have occurred. As already stated HSA co-operated with BEA in the investigation to discover whether there could have been a mechanical malfunction.

It was not strictly part of HSA's business to suggest how BEA should deal with an event which has been shown to be due to operational rather than mechanical faults. They were entitled to assume that there was sufficient liaison between the engineering and operational divisions of BEA to ensure that pilots were apprised of the dangers which Captains Dell and Lowden had seen.

The position of DFS, DTI/ARB

The functions of these two bodies, which up to April 1972 were separate entities, have now been amalgamated under the CAA.

Up to that date the DTI, through the Directorate of Flight Safety, were concerned with operational and the ARB with airworthiness matters. Information was exchanged between the two, but integration was not as close as ideally it should have been. The *Edwards' Report** (paragraph 879) made a point of this and we have evidence that matters are now much improved.

The Orly report, being confidential, was not reported to DTI or ARB.

DTI however received the *BEA Air Safety Review* of May 1970. They also received the BEA Air Safety Committee minute of 25 June 1970 recording Captain Lowden's concern at the incident and his realisation of the potential danger. Mr Neill who was head of the Directorate of Flight Safety explained that owing to the nature of this report it was coded as a mechanical defect. That was accordingly not a matter for him but for ARB. Mr Neill's Department never heard any suggestion that human failure might have been the cause of the incident, and so took no steps.

So far as the ARB were concerned, they became aware of the Foxtrot Hotel incident through the *Air Safety Review* and also through the HSA Confidential Service Report. That contained an item

> Chapter 27 Flight Control. Inadvertent Slat Retraction. On G–AVFH when flap retract was selected after take-off, the slat inadvertently retracted simultaneously. It was noticed that the slat-selector lever was in the 'up' position. Extensive inspection of the control systems revealed no fault. There have been no further reports of a recurrence.

ARB had a representative at Heathrow. He was a Mr Sherring, an inspection surveyor. He is essentially an engineer, and through his hands passed a large number of reports from BEA concerning everything from aircraft incidents to minor technical matters. He enquired from BEA what action was being taken on the report of the Foxtrot Hotel incident when he received it. He was in due course satisfied that there was nothing at fault mechanically, and got no impression of danger from the account given to him. Consequently he made no report to his headquarters. Mr Pardoe, the man responsible at ARB, acknowledged that Mr Sherring's decision not to pass on the incident was in the circumstances correct.

Thus the incident fell neatly between two stools, DTI considered it to be a mechanical defect; ARB were satisfied that it was an operational or human error. Neither took action.

Consequently the opportunity of providing some stimulus to BEA and some support for Captain Lowden's perspicacity was lost.

(iii) Captain Childs

Captain Childs, a very experienced Trident captain, came before us to give evidence about the disquiet which he himself had felt for some time prior to the accident on two aspects of pilots' attitude to the stall warning/recovery system. The first related to the operation of the stall recovery system fail lights. That matter was skilfully explained to his satisfaction in cross-examination of him by Mr Webster for HSA, and need not concern us further.

* *British Air Transport in the Seventies,* Report of the Committee of Inquiry into Civil Air Transport. Cmnd. 4018. HMSO, 1969.

The other matter was more troublesome. It was Captain Childs' custom even before Papa India to question his pilots before flight on what their reactions would be to the operation of the stall warning system. To his astonishment, he said, more than half these pilots suggested pulling the stall recovery over-ride as soon as they felt the stick-shaker. Less than a quarter suggested anti-stall action, but this quarter included those who had had incidents. His impression was that this feeling amongst co-pilots had been engendered by an incident or incidents in the early days of the Trident and by the fear that a false stick-push could push the aircraft into the ground.

Captain Childs told us that he was so concerned at this attitude and the potential dangers it exposed that he went to see no less than four Flight Managers and the DTI Operations Inspector (Captain Forshaw) in order to suggest that the training must be at fault. The Flight Managers concerned, insofar as they remembered his visit at all, had only the haziest recollection of what he had said. Whatever the reason may be, his message did not get across. One had the suspicion that he may have been regarded as a person too ready to complain or criticise and for that reason was not taken altogether seriously. It may also be that he did not make himself as clear to the Flight Managers as he did to us.

However that may be, BEA after Papa India carried out a random check on twenty-one captains who had experience of co-pilots' reaction to actual stall warnings in practice. The results of this showed that in every case the captain was satisfied with the way in which P2 had coped; in every case incidence had been reduced and/or power applied.

How that discrepancy between Captain Childs' impression and the experience of the twenty-one captains can be explained, it is hard to say.

It may be that the co-pilots questioned by Captain Childs thought they were being tested on the malfunctioning of the system and gave the answer they believed the examiner wanted; it may be that the quiz of the twenty-one captains was affected by having taken place after this accident.

In the end it is not of as much significance to the Papa India crash as was at one time thought. The vice of the Papa India situation was that the crew were not forewarned of the possibility of a stick-push almost coincidental with a stick-shake nor of the other implications of a change of configuration stall.

Their potential reactions to a stick-shake in comparatively ordinary circumstances are therefore really immaterial. Indeed the fact that there were three stick-pushes before the system was dumped leads one to the belief that their initial reactions were not altogether at fault.

(iv) FDR Study Group results

In 1971 BEA was starting to reap the benefit of the quick access recorders which they had installed. These carry 64 channels in contrast to the 6 channels of the mandatory instrument. It is possible to check with great accuracy the way in which an aircraft has been handled during any particular flight. The

idea of doing this was not new. There had for some 10 years been in existence the Civil Aviation Airworthiness Data Recording Programme (CAADRP) undertaken jointly by ARB and the Royal Aircraft Establishment, and BEA's programme was a domestic extension of this. Once again industrial relations had to be carefully considered. Pilots disliked having their actions observed and reported on in this way, and it was impolitic, if not impossible, to use the FDR readouts as the sole basis for reprimanding a pilot.

However, by December 1971, information was coming from the BEA FDR Study Group that certain non-standard procedures were occasionally being adopted. The occasions were not frequent, but their number was not insignificant. The most serious ones were early undercarriage retraction and early flap retraction. One individual offender was traced (he was not the Foxtrot Hotel Captain). That individual was tactfully interviewed by his Flight Manager. The whole subject of these malpractices was going to be incorporated into a *Flying Staff Information Bulletin* (FSIB). However, there was some delay in collating the technical information and this resulted in FSIB No 414 being published on 5 June 1972 containing only the introductory information about the Study Group. FSIB No 415 drawing attention to special event searches, in particular early undercarriage and flap retraction, although drafted prior to the accident, was not published until July 1972.

Since this FSIB was drafted before the accident it is important to see what it said.

> The special event search has shown that on a small number of occasions the following occur:
>
> (a) Early undercarriage retraction.
>
> (b) Early flap retraction (below 50 ft radio).
>
> These are actions which are made deliberately and reveal both a disregard for the operating procedures and a lack of appreciation of the aircraft performance. . .
>
> Premature flap retraction results in a reduced stall margin at a very low height . . . A further important point is that the normal noise-abatement sequence of 'Flaps up – power reduction' is broken if the non-handling pilot is unaware of the premature flap retraction and from force of habit he may select the only lever available and inadvertently retract the droop.

Chapter V. Conclusions

The immediate causes of the accident have never been in any real doubt since the original readout of the FDR within a few hours of the accident. The painstaking and wholly admirable work done by the AIB, besides underlining the fact that those immediate causes had been accurately assessed, indicated that there was no major mechanical malfunction involved.

Consequently the task facing us was to try to discover the underlying causes, with a view to preventing so far as possible anything like this accident happening again.

The following matters were those to which we directed our attention:

(a) Why was there such a serious and persistent speed error?

(b) Who moved the droop lever and why?

(c) Why did the monitoring system fail?

(d) Why did the crew fail to diagnose the reason for the operation of the stall recovery system, and why did they fail to fly a recovery and why did they dump the system?

There is a danger of assuming that we have all the facts before us and that the only problem is to assemble them in the right order. Had we had the benefit of a cockpit voice-recorder this might have been true. As it is there may well be some vital piece of information missing which would, if known, change the whole picture.

(i) Why was there such a serious and persistent speed error?

All three pilots on Papa India would be well aware of the importance of maintaining a proper and adequate level of speed, particularly in view of the existing turbulence. The rarity of such a speed error as the one shown here is an indication that there must be some extraordinary reason for it. Where one finds that a second event of even greater rarity, namely the cardiac incident, is happening to the handling pilot at the time, it is difficult as a matter of common sense not to associate the one with the other. The only feasible explanation on the evidence for the steady deterioration in the speed from about second 83 to second 108 is that Captain Key was suffering from pain or malaise which distracted his attention from the speed and also affected his judgment. It is inconceivable, being the sort of pilot he was, that he would not in normal circumstances have taken some steps to put matters right, whether by dialling up the speed or more likely by disengaging the autopilot and manually lowering the nose of the aircraft.

(ii) Who moved the droop lever* and why?

It seems likely that it was either Captain Key or S/O Keighley. S/O Ticehurst had no call to move the lever and if he had, the movement would have been seen and corrected.

Was it S/O Keighley?

The following suggestions were made:

(a) That he may have mistaken the stall-recovery low-pressure light for the droop out of position warning light and therefore moved the droop lever. This is difficult to believe. Speed, height, time and bank-angle were all wrong for droop retraction. It is very doubtful if he would have taken it upon himself to do such a thing. If he had, one would have expected him to have associated the dramatic consequences with what he had done and to have reversed the movement.

(b) That he may have mistaken an order from Captain Key to 'put that up', meaning the new height in the height acquire window, for an order to retract the droops. The same objection applies here. Furthermore, if there was any doubt in his mind, one would have expected him to query such a command.

(c) That Captain Key, for reasons which appear hereafter, may have believed that the flaps had been put down instead of up and may therefore have ordered S/O Keighley to 'put them up' pointing to the droop lever in the belief that it was the flap lever. Again the same objections apply.

Was it Captain Key?

It is probable that there was some connection between the grossly abnormal speed error and Captain Key's physical condition on the one hand, and the movement of the droop lever on the other. By second 108 though no doubt feeling ill, he was probably aware that his speed was far too low. He may have had in the back of his mind the Dublin incident when P2 put down full flap instead of retracting it. Knowing that S/O Keighley was 'P2 only' like the Dublin co-pilot, he may have thought that the same thing had happened and that that was the cause of his low speed. With the state of his reasoning impaired, he may himself have moved the droop lever believing he was retracting the flaps. If so, that would go some way towards explaining why the person who moved the lever failed to associate the consequences with the movement.

Against that must be set the fact that Captain Key was the last person one would expect to make an elementary mistake of that sort, however ill he may have been feeling. Nevertheless, so far as it is possible to speculate on the facts we have available, this explanation is the least unlikely.

* Accidental movement, for example by someone's sleeve, can be ruled out. The lever has to be removed from its gate and requires appreciable force to shift it forwards.

What seems inescapable is that the reason for the movement of the lever lies either in the inexperience of S/O Keighley or in the impaired mental faculties of Captain Key or in a combination of both.

In the end, the problem of whose hand it was assumes less importance than the questions which follow.

(iii) Why did the monitoring system fail?

Monitoring involves two separate processes: alertness to observe errors and the experience and confidence to correct them.

So far as the speed errors are concerned there seems no possible reason apart from inattention why they should not have been observed, certainly by S/O Ticehurst. S/O Keighley may have been too intent on reducing thrust to the correct figure to observe the airspeed indicator. If S/O Ticehurst did observe the speed, it was his duty to bring the discrepancy to the notice of the Captain by shouting 'Speed, speed' over the intercom. The likelihood is that he did not observe the error. First because at the very moment when the speed was at its lowest at about second 108 he must have been making the final entry in his log, an action which he would have postponed if he had been as concerned as he should have been. Secondly, because he must have noticed the movement of the droop lever had he been watching the instruments and the handling pilot as closely as the situation demanded.

In fairness to S/O Ticehurst, even if he had been shouting 'Speed' as he should, it would scarcely have occurred to him that illness might be the reason for Captain Key taking no action.

Neither he nor S/O Keighley had been apprised of the dangers of subtle incapacitation.*

So far as S/O Keighley was concerned, even if he did observe the speed errors, it is doubtful whether he had the experience or self-assurance to bring them to the notice of the Captain as rapidly and as forcefully as he should. If Captain Key's incapacity had been recognised it would have been S/O Keighley who would have had the formidable task of taking over from the Captain.

So far as the failure to observe the movement of the droop lever is concerned, this is equally difficult to understand. It is precisely the type of action which the monitoring system is designed to pick up and correct. That should have happened here. If it had, there would have been no accident.

On the assumption that Captain Key moved the lever there are two possible reasons for S/O Keighley not observing the movement. If he had his left armrest in the horizontal position which some co-pilots then favoured,† this would have impeded his view of the droop lever. If he had taken rather longer than normal to reduce thrust to the correct level, his extended left arm might also at second 114 have prevented him from seeing the droop lever.

* See Chapter IV B(ii)

† This practice has now been stopped.

S/O Ticehurst's failure to observe the droop lever movement is less readily understandable. Various suggestions were put forward. That he was operating the transponder; but this would scarcely take his eyes away from the front at all. That he had turned round to check the dolls' eyes on the systems panel. This is on the assumption that there had been a transient stick-shake at about second 103. If there had been such a warning one would have expected speed to have been increased. It was not. In any event S/O Ticehurst would presumably have ensured that the situation was stabilised before he concerned himself with the dolls' eyes.

A further possibility advanced is that Captain Key at some stage suffered an obvious collapse and that S/O Ticehurst's attention was thereby distracted from his monitoring duties. We are only concerned here with the period of time up to second 116. At second 116, when the autopilot disengaged, all those on the flight deck would undoubtedly be alerted.

At second 108 Captain Key is making his final R/T communication 'Up to 60'. It is true that the message was unduly terse. He should have given his aircraft prefix; he should have said 'Up to flight level 60'; he should have acknowledged the instruction to squawk. Those omissions are not sufficient to indicate imminent collapse, particularly when his tone of voice appears to be normal.

It does not seem reasonably possible that Captain Key collapsed during those vital 8 seconds from 108 to 116.* Any obvious symptoms short of collapse would have meant that S/O Ticehurst would have been doubly attentive and would have observed the droop lever movement.

The only possible conclusion is that for some reason S/O Ticehurst's attention wandered. He may have felt that once noise-abatement procedures were over he could afford to relax. This period of flight was described by one very experienced pilot as 'the most relaxed period of the whole [take-off and initial climb] operation'. It may well be that Captain Collins' presence on the flight deck alongside him provided some distraction. Whatever the reason he almost certainly failed to monitor the speed and must have missed the movement of the droop lever entirely.

There are accordingly three possible reasons why the monitoring system failed. Inattention or distraction; lack of training for subtle incapacitation; inexperience.

Inattention or distraction

There is little one can do to remedy inefficient monitoring except to underline the necessity of vigilance throughout the initial climb, and to obviate potential distractions. Captain Collins' presence on the flight deck, which served no useful purpose, is the most likely cause of S/O Ticehurst's wandering attention.

* There is in fact ample evidence from Figures 1 and 5 of pilot input up to at least second 124 when the second stick-push took place.

Subtle incapacitation

The present method of training, which is aimed exclusively at the situation where one member of the crew suffers an obvious collapse, is not enough. Subtle incapacitation may be a rare event, but what has already been set out in Chapter IV B(ii) shows that it may be a very dangerous one.

Pilots should at least be alerted to the possibility of such an emergency.

We appreciate that it is a matter to which careful thought will have to be given. Taking over the handling of an aircraft unbidden from the Captain is a serious matter, but it is no good closing one's eyes to the possibility that it may be necessary, albeit on very rare occasions, to do so.

Inexperience

When he first starts his line training on scheduled flights the co-pilot will have done about 30 hours actual flying in a Trident including some 10 at the controls. Line Training Captains with whom he will be flying for the next few sectors or so are no more immune from sudden physical incapacitation of one sort or another than anyone else. It is doubtful whether a P2 with the experience outlined above can fairly be expected to cope adequately with such a situation if it arises at a critical stage of flight, as it may.

We consider that the system should be altered. BEA have done something towards this end by altering the brown-line system as already explained.

This will have the desirable effect of ensuring that one at least of the co-pilots will be well experienced. Strengthening one link, however, does not necessarily improve the quality of the chain. The more important thing, we consider, is to provide the trainee with more actual flight deck experience before his line-flying begins. We were given figures illustrating the practice of other airlines in this matter. They did not in the end prove to be helpful; there were too many unknown factors.

We appreciate that it may be difficult to give the requisite experience or indeed to determine how much should be given.

It should not however be beyond the bounds of ingenuity to devise some system. For example, it might be possible to put the trainee in the P4 seat for a number of sectors. He will at least see other people performing their monitoring duties, he will become familiar with the vagaries of strange airports, he will see abnormal situations arising and being efficiently handled. Such experience can, we think, do nothing but good and will help to give that sort of experience and confidence which at present may be deficient.

There are other lessons to be learnt.

When a cadet's training as P2 and P3 is completed, his BEA Training File goes to his Flight Manager, who is then made aware of any particular shortcomings.

S/O Keighley's training, as it happened, was not completed. He was fully equipped as P2 but not as P3, for reasons already set out.

There is no doubt in retrospect that S/O Keighley's Flight Manager should have seen the training reports before Line Training started. This was a pilot who needed sympathetic handling. He should have been seen by his Flight Manager, welcomed to the Flight and made to understand that the Flight Manager or his Assistant were there to help him at any time if he wanted help. In fact his Flight Manager had never seen him, although two months had passed since his arrival, and his training reports had not yet been made available. BEA made it clear to us that in future the management will be more sensitive to the fact that arrival at the operational flight must be a moment of great significance to a young pilot. If genuine interest and concern is shown by the Flight Manager at this point, it will at least give a start to the sort of co-operation between pilot and management which is so desirable.

(iv) Why did the crew fail to diagnose the trouble?

Enough has already been said about the warning systems to make it plain that there was no shortage of indications to the crew that something was amiss. Our own experience on the simulator was shared by pilots of very long experience, namely that by the handling pilot at least the plethora of purely visual warnings went unnoticed. Directly the stick-pusher operated all concentration was directed on the ASI, the attitude indicator and the startling movement of the control column. We at least knew what was going to happen. To someone who was not expecting such an event the combination of audio warning and stick-push would be overwhelming. This no doubt was the reason for P2 in Foxtrot Hotel being convinced there was no CWS warning.

The chances of Captain Key in his physical state or S/O Keighley with his degree of experience being able to pick up the fact that the configuration of the aircraft had changed were remote. S/O Ticehurst was in a somewhat more detached position, but on the hypothesis that his attention had been distracted from the instruments by something happening alongside him, the warnings must have come as an equally inexplicable shock to him. It is perhaps less excusable, but still understandable, that he failed to spot the trouble.

Why was no recovery flown?

The various methods which would have been adopted to fly the aircraft out of trouble have already been explained. Even if action had been delayed to a point immediately after the stick-pusher was dumped they could still have recovered the aircraft. Unfortunately that way of expressing the matter begs the question. If one could have asked the crew at second 127 why they were not flying a recovery, they would surely have said, 'a recovery from what?'. To them, with no reason to suppose that the droops had been retracted, the speed of the aircraft seemed safe, and the attitude normal. The one thing telling them that action was required was the stick-pusher.

They had not been told of the possibility of a change of configuration stall, they had not experienced or been told of the possibility of a practically unheralded stick-push or what such an occurrence might indicate. In the circumstances it would have required greater faith in the stall recovery system

than could be expected of them to have obeyed its dictates blindly. P2 in the Foxtrot Hotel incident put the matter in this way:

> If you are in a situation whereby you find you are getting stick-pushes one after the other which are in effect pushing you into the ground and there does not appear to be any reason for this, after a certain period of time you will assume that it is false, and, when you assume that, the obvious thing to do is to stop the aircraft being pushed down, and that entails pulling the override lever.

The crew's state of knowledge being what it was, the decision to dump was inevitable.

Had they known that almost the only reason which could account for a practically simultaneous stick-shake and stick-push was an untimely retraction of the droops, and, conversely, had they known that by retracting the droops at this speed and incidence the aircraft, without any change of attitude, would be projected into the stall regime, there would at least have been a chance of their appreciating the situation and taking the appropriate action to recover.

After the Foxtrot Hotel and Orly incidents had been reported and after the FDR Study Group findings were known BEA ought to have realised, if they did not, that there was an appreciable risk of premature droop retraction at a dangerous speed. It is true that up to that time the reported incidents had resulted from departures from standard drills. It is not however much good relying on the protective effect of standard drills when the evidence shows that standard drills are being disregarded on a not-insignificant number of occasions.

It was perhaps too much to expect BEA at that stage to have speed-operated baulks fitted to the droop lever mechanism, although this is something which Captain Dell did in fact consider in August 1970. As noted earlier, no aircraft in the world is at present equipped with such devices.

What could have been done without difficulty was to draw the attention of pilots to the effect of premature droop retraction, the almost simultaneous stick-shake/stick-push and the other matters disclosed by Foxtrot Hotel. It could have been pointed out that the steady progression from stick-shake to stick-push, which was one of the aims of the design and a feature of the training programme, could not in these circumstances be expected. It could have been pointed out that if an instant stick-push was experienced in circumstances where a dynamic stall could be ruled out, the probability would be that the droops had been retracted prematurely.

We are alive to the dangers of retrospective wisdom, but from the crew reports actually made on those incidents, the dangers were there to be seen. Moreover the contemporary notes and memoranda show that the dangers were appreciated, at least by Captains Dell and Lowden. Captain Lowden in particular demonstrated commendable foresight.

Nor have we overlooked the fact that in an organization the size of BEA there is no shortage of incidents and reports of incidents. However, the stall warning and recovery systems were from the beginning of the greatest importance to the certification and safety of the aircraft.

Anything which so closely affected the operation of these systems, the pilots' knowledge of how they operated and the training programme, should have been taken more seriously than it was.

In short, mistaken retraction of the droop had all along been recognised as a possibility in the overshoot situation. There was clear evidence that the danger existed also on the initial climb. It was not sufficient to rely on the observance of standard procedures and the efficacy of the stall recovery system, particularly when the latter would in the circumstances operate in an unconventional and unexpected manner, and would therefore probably be disbelieved.

The matter should have been the subject of an FSIB in the first instance, and in due course amendments should have been made to the training syllabus to cover these points.

If as seems probable there was some doubt on the operational side of management as to the precise effect of premature retraction of the droops, those doubts should to some extent have been resolved by the reports of the incidents themselves and could have been easily set at rest by consultation with the engineering-design side.

Summary

The immediate causes of the accident were these:

(1) A failure by Captain Key to achieve and maintain adequate speed after noise-abatement procedures.

(2) Retraction of the droops at some 60 knots below the proper speed causing the aircraft to enter the stall regime and the stick-shaker and pusher to operate.

(3) Failure by the crew to monitor the speed errors and to observe the movement of the droop lever.

(4) Failure by the crew to diagnose the reason for the stick-pusher operation and the concomitant warnings.

(5) The dumping by the crew of the stall recovery system.

The underlying causes were these:

(1) The abnormal heart condition of Captain Key leading to lack of concentration and impaired judgment sufficient to account for his toleration of the speed errors and to his retraction of, or order to retract, the droops in mistake for the flaps.

(2) Some distraction, the nature of which is uncertain, possibly due to the presence of Captain Collins as a passenger on the flight deck, which caused S/O Ticehurst's attention to wander from his monitoring duties.

(3) Lack of training directed at the possibility of 'subtle' pilot incapacitation.

(4) Lack of experience in S/O Keighley.

(5) Lack of knowledge in the crew of the possibility or implications of a change of configuration stall.

(6) Lack of knowledge on the part of the crew that a stick-shake and push might be experienced almost simultaneously and of the probable cause of such an event.

(7) Lack of any mechanism to prevent retraction of the droops at too low a speed after flap-retraction.

Chapter VI. Cockpit voice recorders

There is at present no legal requirement for the carriage of cockpit voice recorders on aircraft registered in the United Kingdom. Article 13(2) of the Air Navigation Order 1972 and Schedule 5 thereof requires no more than a simple five-parameter Flight Data Recorder on certain specified types of aircraft.

This accident has shown that data as to the height, speed, attitude and movement of the controls of the aircraft, however valuable as eliminating any suggestion of mechanical failure, do not always provide as full a picture as possible. The investigator is still left in the dark as to what was passing between the crew members by way of orders, comment or exclamation. Had we been furnished with that sort of information, it might well have established why the droop lever was moved forward, the identity of the person who moved it, the reactions of the crew thereafter and as a consequence the underlying causes of the crash.

There must be some area of uncertainty in every accident, but the more these areas can be reduced the greater the prospect of eliminating the possibility of a recurrence.

It seems to us that a requirement for the installation of cockpit voice recorders in airline aircraft (ie, those of over 27,000 kilograms all-up weight) is overdue.

In 1969 the Directorate of Flight Safety, Department of Trade and Industry, in conjunction with the AIB, drafted revised requirements for flight data recording, including provisions for the fitting of cockpit voice recorders in all aircraft of this type for which a Certificate of Airworthiness was first issued after mid-1972. These proposals met with opposition, and a Working Party was formed in 1970 to reconsider the whole matter of FDRs and CVRs and to make recommendations.

The Working Party reported in May 1971 that in their view 'existing' aircraft (ie, those certificated prior to April 1971) should be required to add three more parameters to the existing five on the FDRs, and that 'future aircraft' (those certificated after April 1971) should be required to carry a large capacity FDR *and* a CVR. These recommendations were accepted in principle by the Department of Trade and Industry, and the CAA have recently (December 1972) proposed amendments to the Air Navigation Order 1972. These reflect in the main the recommendations of the Working Party but recommend that the changes should not come into force until 1 January 1975.

This, at least as far as CVRs is concerned, we do not regard as satisfactory.

CVRs were first introduced in Australia in January 1965 and soon afterwards by the United States. They are fitted as standard equipment to all BOAC's 747s and most large United States transport aircraft. It is nearly four years since the first proposal for their adoption in this country was made. We understand that BALPA despite earlier misgivings are now in favour of them.

The time has come for expedition.

Chapter VII. Noise-abatement

The noise-abatement procedure did affect Papa India, in that the reduction in thrust was one of the causes of the loss of speed. In one sense any procedure which demands that an aircraft should fly at less than its optimum power for that stage of flight is undesirable. However, aeronautical and social considerations have to be blended as best as possible.

We take the view that the procedures which governed Papa India's flight were safe and were not too demanding either on crew or aircraft.

We do not propose to make any recommendation or suggestion under this head. Both BEA and HSA have devised new noise-abatement procedures. We express no views thereon.

Chapter VIII. Recommendations and observations

We recognise and applaud the fact that the parties, and particularly BEA, have already taken steps to implement in advance much of what follows:

1. The dangers inherent in premature retraction of the leading-edge droops or slats are demonstrably so great that a speed-operated baulk to prevent such retraction is required and we so recommend.
2. We recommend that specific instruction and training should in future be given to pilots on the following subjects:
   (a) The causes and results of a 'change of configuration' stall.
   (b) Circumstances in which the stick-pusher may operate almost simultaneously with the stick-shaker.
   (c) The difference in design concept between the stick-shaker and the stick-pusher mechanisms.
3. We recommend that the carrying of cockpit voice recorders should as soon as is practicable be made a mandatory requirement on all civil passenger-carrying aircraft of more than 27,000 kg auw.
4. We suggest that the attention of pilots should be drawn to the possibility and dangers of subtle as well as obvious pilot incapacitation.
5. We recommend that young trainee pilots should be given more experience than at present on the flight deck of the aircraft before being permitted to operate as P2 on passenger-carrying flights. The extent of that extra experience should be the subject of discussion between airline and CAA. It should be enough to give the trainee the opportunity of seeing a variety of crews flying operational sectors before he himself acts as P2.
6. We recommend that should the 'stress-test' electrocardiogram in future become significantly more reliable it should be substituted for the present 'resting' ECG. This matter should be kept under review.
7. We question the desirability of allowing the P4 seat to be occupied during critical stages of flight by anyone except a person having a flight function to perform or under training.
8. We suggest that pilots' folding arm-rests on the Trident should always be kept in the stowed position during take-off, initial climb, approach and landing.

9. We suggest that BEA should consider whether their Air Safety Branch could not be made more effective by giving the Air Safety Officer greater authority to direct investigation of potentially dangerous incidents. There are at present, it seems to us, too many different organisations concerned in this vital matter, with the result that responsibility and enthusiasm may be diluted.

10. We suggest that CAA should encourage closer co-operation between their operational and airworthiness branches.

Chapter IX. Answers to questions

Civil Aviation (Investigation of Accidents) Regulations 1969. Regulation 16(13)

Accident involving Trident G–ARPI

Notice of Inquiry

Final Questions

1. *Was the aircraft fit to perform the intended flight? If not, in what respects was it unfit?*

   Yes.

2. (a) *How many passengers and crew were carried in the aircraft on its last flight?*

   There were 3 flight crew, 3 cabin crew and 112 passengers being carried.

   (b) *Was the aircraft properly loaded and trimmed before take-off?*

   The aircraft was some 24 kilograms overweight on take-off and the centre of gravity was marginally forward of BEA limits though within the specified range of the *Flight Manual.* These matters had no effect on subsequent events.

3. (a) *How many pilots were carried on the flight-deck for its last flight?*

   There were four pilots carried on the flight-deck for the last flight. Three of these were flight crew, one was a passenger.

   (b) *Had they been properly trained and were they adequately experienced to perform their duties?*

   So far as the three flight crew were concerned, Captain Key and S/O Ticehurst were properly trained and adequately experienced to perform their duties. S/O Keighley was properly trained but we doubt whether he was adequately experienced.

   (c) *Were they physically and mentally fit for their duties?*

   S/O Ticehurst and S/O Keighley were physically and mentally fit for their duties. Captain Key was not physically fit to perform his duties by reason of the chronic abnormal condition of his coronary arteries and an acute condition in one of them. He was mentally fit except insofar as his acute abnormal physical condition may have affected him mentally.

(d) *Were they duly licensed to perform their duties?*

Yes.

4. *Did the Air Traffic Control service function efficiently during the flight?*

Yes.

5. *Was there any defect, malfunction or failure of the aircraft's air frame, powerplants, instruments or equipment before impact?*

(a) The three-way cock in the pneumatic stick-pusher system had not been wire-locked in its operating position as it should have been. The cock was one-sixth of a turn out of its proper position on impact.

(b) A pressure-reducing valve in the same system was unserviceable.

6. (a) *Were the flight procedures laid down for take-off and climb (including those relating to noise-abatement) safe and practicable?*

Yes.

(b) *Were these procedures followed?*

No.

(c) *If not, in what respects and why were they departed from?*

The procedures were departed from in that the proper speed levels were not maintained; the droops were retracted some two minutes too soon, 1,300 feet too low, at about 60 knots under the placarded retraction speed and in a banked turn.

They were departed from, so far as we can determine, probably because of the medical condition of Captain Key, the inexperience of S/O Keighley, and the inattention of S/O Ticehurst.

(d) *What action was thereafter taken by the pilots or any of them?*

So far as can be ascertained, there was some small attempt to reduce the incidence of the aircraft after the stick-pusher mechanism had operated and the port bank-angle was taken off. After the third stick-push the stall recovery override lever was operated. It is not possible to say what other action if any was taken by any of the pilots.

(e) *What action could have been taken by the pilots or any of them to prevent this accident after the flight procedures had been departed from?*

The actions which could have been taken by the flight-crew to prevent the accident after the said departures from the flight procedures are as follows:

(i) Re-selection of the droops to the extended position.

(ii) Reduction of incidence by holding the control-column forward of the trim position after the stick-push had operated.

(iii) Allowing the stick-push to continue to operate until a speed of about 200 knots was achieved.

(iv) Increase of thrust.

7. *What was or were the cause or causes of this accident?*

The immediate causes of the accident were as follows:

(a) A failure by the handling pilot to achieve and maintain adequate speed after noise-abatement procedures.

(b) Retraction of the droops at some 60 knots below the proper speed causing the aircraft to enter the stall regime.

(c) Failure by the crew to monitor the speed error and to observe the movement of the droop lever.

(d) Failure by the crew to diagnose the reason for the stick-pusher operation and the concomitant warnings.

(e) Operation of the stall recovery override lever.

The underlying causes were these:

(a) The abnormal heart condition of Captain Key leading to lack of concentration and impaired judgment sufficient to account for his toleration of the speed error and (possibly) his retraction of or order to retract the droops in mistake for the flaps.

(b) Some distraction, possibly to be found in the presence of Captain Collins, which caused S/O Ticehurst's attention to wander from his monitoring duties.

(c) Lack of training in the dangers of subtle pilot incapacitation.

(d) Lack of experience in S/O Keighley.

(e) Lack of knowledge in the crew of the possibility or implications of a change of configuration stall.

(f) Lack of knowledge on the part of the crew that a stick-shake and push might be experienced almost simultaneously and of the probable cause of such an event.

(g) Lack of any mechanism to prevent retraction of the droops at too low a speed after flap retraction.

8. *What steps ought to be taken to prevent a recurrence?*

The following steps ought to be taken to prevent a recurrence:

(a) A speed-operated baulk should be provided to prevent premature droop/slat retraction.

(b) Specific instruction and training should in future be given to Trident pilots on the following subjects:

(i) The causes and results of a change of configuration stall.

(ii) Circumstances in which the stick-shaker may operate almost simultaneously with the stick-pusher.

(iii) The difference in design concept between the stick-shaker and stick-pusher mechanisms.

(c) The attention of pilots should be drawn to the possibility and dangers of subtle as well as obvious pilot incapacitation.

(d) Young trainee pilots should be given more experience than at present on the flight deck of the aircraft before being permitted to operate as P2 on passenger-carrying flights.

(e) The possibility of using 'stress test' electrocardiograms should be kept under review.

(f) Consideration should be given to the question whether it is desirable to allow the P4 seat to be occupied during critical stages of flight by anyone except a person having a flight function to perform or under training.

(g) Pilots' folding arm-rests on the Trident should be kept in the stowed position during take-off, initial climb, approach and landing.

(h) BEA's Air Safety Branch should be revitalised and given more authority.

(i) Although strictly speaking it is not designed 'to prevent a recurrence', we recommend the provision of cockpit voice recorders on all civil passenger-carrying aircraft of more than 27,000 kg auw.

9. *Were all proper steps taken by the rescue services after impact to save life?*

Yes.

Geoffrey Lane — *Commissioner*

Morien Morgan, J W Jessop — *Assessors*