

INCIDENT

Aircraft Type and Registration:	Dornier 328 100, TF-CSB
No & Type of Engines:	2 Pratt and Whitney 119B turboprop engines
Year of Manufacture:	1997
Date & Time (UTC):	22 June 2006 at 1952 hrs
Location:	Aberdeen Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - 16
Injuries:	Crew - None Passengers - None
Nature of Damage:	Minor damage to wheels
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	62 years
Commander's Flying Experience:	13,000 hours (of which 300 were on type) Last 90 days - 111 hours Last 28 days - 64 hours
Information Source:	AAIB Field Investigation

Synopsis

During the landing roll, the crew could not decelerate the aircraft sufficiently because they were unable, repeatedly, to select the power levers into the beta range. The aircraft overran the runway and the Runway End Safety Area, coming to rest some 350 metres beyond the end of the runway. There were no injuries. Three Safety Recommendations are made.

History of the flight

The aircraft departed Stavanger at 1850 hours on a scheduled commercial air transport (passenger) flight to Aberdeen with the commander, co-pilot, one cabin crew member, and 16 passengers on board. The co-pilot flew the sector and before descent, he briefed for a radar-vectored visual approach to Aberdeen's

Runway 34. The flight crew obtained ATIS¹ information which indicated that the surface wind was from 300° at 7 kt, visibility was greater than 10 km, and the lowest cloud was one or two octas² at 1,500 ft. The ATIS described the runway as being wet along its entire length, though the flight crew later recalled that the runway was dry. The approach was flown normally with flaps at 20°; the final approach speed was 121 kt. The crew were visual with the runway approximately nine miles from touchdown, and were cleared by Air Traffic Control (ATC) for a visual approach on their request.

Footnote

¹ Automatic Terminal Information Service.

² Or 'eighths' of the visible sky covered by cloud.

With the aircraft approximately seven miles from touchdown, ATC transmitted that the surface wind was from 300° at 5 kt. The co-pilot then disconnected the autopilot and began configuring the aircraft for the approach. Slightly more than three miles from touchdown, the flaps were selected to 20°, and the propeller condition levers were set to maximum; the flight crew then completed the 'Final Approach' checklist. The target speed for the final approach was 121 kt, and the aircraft's speed stabilised at about 120 kt. Approximately two miles from touchdown, the aircraft had deviated slightly below the glideslope and a 'soft' EGPWS³ "GLIDESLOPE" annunciation was generated. The co-pilot acknowledged the annunciation, re-confirmed to the commander that he had visual contact with the runway, and re-established the aircraft on the glideslope.

As the aircraft descended through 50 ft radio altitude, the power levers were retarded and the co-pilot began the flare. The touchdown occurred approximately 530 metres from the runway threshold (with approximately 1,300 metres of runway remaining) at an airspeed of 105 kt. The commander stated later that the touchdown was a little further along the runway than he would have preferred, but he considered it to be entirely safe. After touchdown, the co-pilot attempted to select the power levers into the beta range. (Selection of the beta range produces considerable deceleration, as the propellers 'disc' and provide drag.) The co-pilot found, however, that he was unable to move the latches on the power levers which prevent inadvertent selection of the beta range below flight idle. In accordance with normal practice for this situation he advanced and then retarded the power levers again, and made a second attempt to select the beta range, but found that the latches would still not disengage.

Footnote

³ Enhanced Ground Proximity Warning System (EGPWS).

The co-pilot said to the commander "WE DON'T HAVE BETAS". The commander took control, applied heavy braking, and made four further attempts to achieve the beta range, each time smartly advancing the power levers and then retarding them to the flight idle stop, before attempting to disengage the latches. These attempts were also fruitless. He transmitted to ATC that the aircraft was in difficulties.

The tower controller activated the crash alarm, alerting both the airport and local authority emergency services by means of an Omnicrash⁴ system.

As the aircraft approached the end of the runway the commander steered the aircraft to the left to avoid colliding with the approach lights and localiser antenna on the extended runway centreline. The aircraft left the end of the runway surface at about 43 kt, and continued across grassy terrain beyond the runway end. Recognising that the aircraft had left the runway, the cabin crew member instructed the passengers to adopt the 'brace' position, and braced herself. As the aircraft travelled across the grass, the commander attempted to shut down the engines, but found that the rough ride made grasping and moving the condition levers and their latches awkward. The engines were shut down and the aircraft came to a standstill some 350 metres beyond the runway end. The ground spoilers remained stowed throughout the landing roll.

After the aircraft had come to rest, the commander made a Public Address (PA) announcement to the passengers, instructing them to remain seated and explaining to them that the crew had experienced "A STUCK THROTTLE". The flight crew completed the 'Shutdown' checklist and the commander then left the flight deck and entered the

Footnote

⁴ Omnicrash is a system which enables simultaneous telephone communication with various emergency services.

passenger cabin, where he spoke to the passengers about the incident.

The aircraft sustained no apparent damage and all on board were uninjured. The Rescue and Fire Fighting Service (RFFS) attended the aircraft and the passengers disembarked normally.

Initial engineering evaluation

The aircraft was initially examined where it had come to rest, in a grassed area some 350 metres beyond the end of Runway 34. No obvious damage was evident. Tyre skid markings consistent with heavy braking on all four main-wheels were evident, beginning towards the over-run end of the paved surface. These began close to the centre-line and deviated to the right before deviating progressively to the left. They indicated that the aircraft departed the paved surface close to the junction of Runway 34 with Taxiway 'W' by the Runway 19 threshold, travelling at an angle to the left of the centreline. Wheel marks on the grass showed that the aircraft then turned back until it was travelling parallel with the runway, but significantly to the left of the extended centreline.

The previous flight

During the previous landing at Stavanger, the co-pilot had experienced difficulties in operating the latches to reduce below flight idle. He had brought this to the attention of the commander, who had assisted successfully with the selection. The landing had been otherwise normal and the aircraft decelerated to taxi speed well before the end of the runway.

Flight Recorders

General

The aircraft was equipped with a solid state Flight Data

Recorder (FDR) that was capable of recording and retaining data for a minimum duration of 25 hours, and a solid state Cockpit Voice Recorder (CVR) that was capable of recording 120 minutes of communication and ambient sound from the cockpit environment. The recorders were removed and replayed at the AAIB. Data for the incident flight was available from both recorders.

Recorded Data

Times quoted are FDR-recorded UTC. Extracts from the CVR are in "SMALL CAPITALS". Aircraft heading is magnetic, airspeed is Knots Calibrated AirSpeed (KCAS) and altitudes are referenced to altitude above mean sea level (amsl) unless otherwise stated.

Figure 1 provides the salient parameters of the final approach and landing. As the aircraft passed through 50 ft radio altitude, the power levers were retarded and the aircraft started to flare; airspeed was 119 kt. The aircraft touched down approximately 530 metres from the threshold of Runway 34 (approximately 1,300 metres from the end of the runway), at an airspeed of about 105 kt (a ground speed of 109 kt). Almost immediately the engine torque started to increase (from about 5% to 40%) before rapidly decreasing (Figure 1, point A), at which point the aircraft started to settle on to its wheels and the ground speed started to reduce. The engine torque then rapidly increased and decreased twice in quick succession (Figure 1, point B) and the aircraft momentarily became light on both main gears. During the second engine torque increase the co-pilot said "WE DON'T HAVE BETAS" to which the commander acknowledged "NO"; the aircraft was about 600 metres from the end of the runway and ground speed was about 92 kt.

Ground speed continued to reduce, but engine torque continued to increase. When the aircraft was

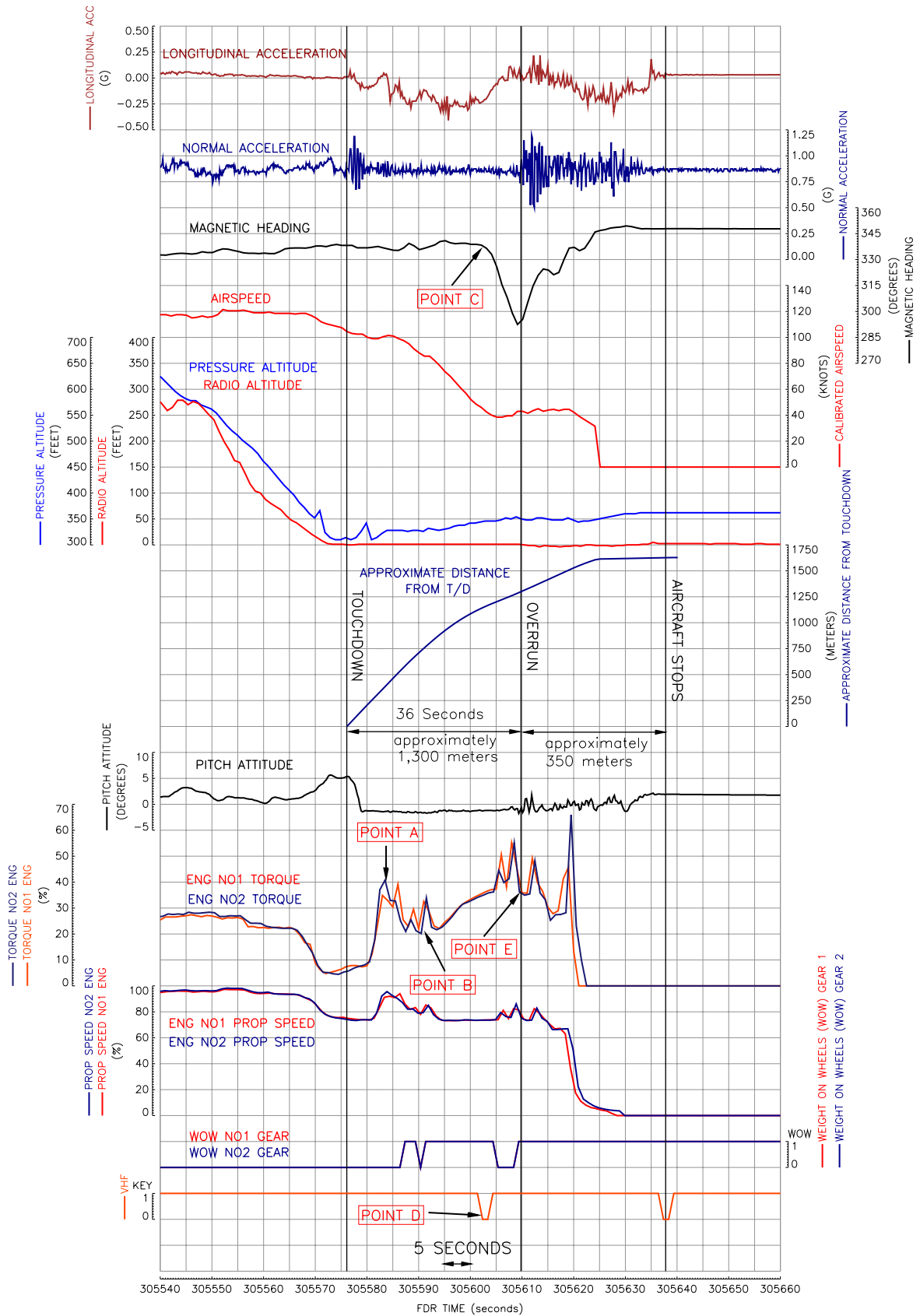


Figure 1

Salient FDR Parameters

approximately 190 metres from the end of the runway it started to deviate from the runway centre line (Figure 1, point C), turning to the left, almost coincidentally the commander advised the tower “WE GOT A PROBLEM” (Figure 1, point D) ; ground speed was about 40 kt and engine torque was at 37%.

When the aircraft was approximately 150 metres from the end of the runway the engine torque increased and decreased rapidly again (Figure 1, point E), the aircraft became momentarily light on both main gears and started to accelerate slightly. As the aircraft overran the end of the runway ground speed was about 43 kt, and it turned left reaching a heading of 299°. The aircraft then started to turn to the right again and the engine torque increased and decreased twice, in rapid succession, before the commander gave the instruction to shut down the engines; the aircraft was approximately 300 metres beyond the end of the runway at the time. As the engines ran down the aircraft started to decelerate, eventually coming to a stop approximately 350 metres beyond the end of the runway on a heading of 348°. During the landing the ground spoilers had remained stowed.

After coming to a stop, the commander gave a brief to the passengers, during which he explained “WE HAD A STUCK THROTTLE”. ATC advised the crew that the RFFS were on the way and the crew proceeded with the shutdown checklist. As the crew shut the aircraft down, the co-pilot said “IT WOULDN’T MOVE”. RFFS personnel then arrived and boarded the aircraft, during which the commander was heard to say “THE PROPS WOULDN’T MOVE BACK...I USED MAXIMUM BRAKING BUT IT JUST WOULDN’T HOLD IT SO I SHUTDOWN THE ENGINES AS WE LEFT THE RUNWAY”. Battery power was removed at 1957 hrs at which time the recorders ceased to function.

The power levers and the flight idle baulk

The aircraft’s power levers are fitted with mechanical baulks to prevent inappropriate selections. One baulk prevents selection of settings below flight idle unless certain conditions are met. To select settings below flight idle (after landing or in the event of a rejected takeoff), the pilot must first ensure that the power levers are at the flight idle position, and then pull two latches (one on each power lever) upwards to disengage the locks, before retarding the power levers below flight idle into the beta range. Further rearward movement of the power levers causes selection of increasing amounts of reverse thrust. The latches are operated with the tips of the fingers, whilst the palm of the hand rests on (or grasps) the power lever itself (see Figure 2).

Landing technique

Both pilots stated that it was normal to select the power levers to flight idle just before touchdown, and that selection of the beta range once the aircraft had landed, caused adequate deceleration. They stated that it was unusual to use the aircraft brakes on landing until a fast taxi speed had been achieved.

The company was operating under another organisation’s Air Operator’s Certificate, and using the relevant operations manual. The operations manual section entitled ‘*Standard Operating Procedures*’ included the following remarks in the section on ‘*Landing*’:

It is vital that the power levers are moved to the flight idle position BEFORE attempting to lift the latches and continue to ground idle. There have been instances of premature lifting of these latches causing the power levers to become jammed. If the power levers are left in flight idle residual torque will exceed 30% and it will be difficult to stop the aircraft without damage. Should this



Figure 2

Power levers and latches

situation arise, the pilot flying should release the latches and push the power levers forward with the flat of his hand. He should then bring the power levers smartly backwards to the flight idle position before attempting to lift the latches and continue to ground idle’.

Following a fatal accident in Genoa, Italy, in 1999 (see ‘Previous incidents’ below), two additional paragraphs were inserted into the airplane operating manual.

The first, headed ‘*Balked Landing*’ stated:

‘whenever the captain deems it necessary to discontinue landing roll to avoid a catastrophic

situation after touch down, given sufficient runway length is remaining, he may apply the following balked landing procedure:

- POWER levers (both)..... Set GA TQ*
- GA button.....Press*
- T/O config warning.....Disregard*
- Accelerate airplane.....V_{REF}*
- Airplane.....Rotate to GA-FD
bar (8°)*
- Once airborne*
- GO-AROUND procedure.....Apply*

This manoeuvre is an emergency evasive action, and may be practised in the simulator only.’

One UK operator of a fleet of Dornier 328 aircraft stated that their flight crews were routinely trained in this procedure during simulator training. The operator of TF-CSB did not carry out similar training.

The second additional paragraph, headed 'Power Lever Gate', stated:

'Certification requirements demand means to prevent inadvertent operation of reverse thrust and propeller settings below the flight regime. These means must have a positive lock or stop at the flight idle position and must require a separate and distinct operation by the crew to displace the control from the flight regime.

The power lever gate of the Dornier 328 has been designed accordingly. For a selection of power settings below Flight Idle the Power Levers must be retarded to the Flight Idle position stop first (Hands off the latches) before the latch handles are lifted and lower Power Lever settings can be selected after landing.

Also be aware, that if the Power Levers are not completely retarded to the Flight Idle stop they may be positioned at Location "X" (see Figures 3 and 4). If this occurs the latches cannot be lifted at all and the Power Levers may jam if rearward pressure is on the latches. If the latches are lifted before Flight Idle, the Power Levers cannot be moved beyond the stop shown in the Power Lever Gate thus preventing the selection of Flight Idle and non-flight regimes.

NOTE: *If this happens*

- 1. Remove any backpressure on the Power Levers and release the latches completely.*
- 2. Hold the Power Lever only and smartly retard the Lever to Flight Idle.*
- 3. Normal selection to Ground Idle is now possible.*
- 4. If the Power Lever still cannot be moved below the Flight Idle position, the aircraft can be stopped by applying maximum braking while maintaining a wings level attitude.'*

Stop prevents pilot from inadvertent selection of a position below Flight Idle during flight when retarding Power Lever with latch lifted

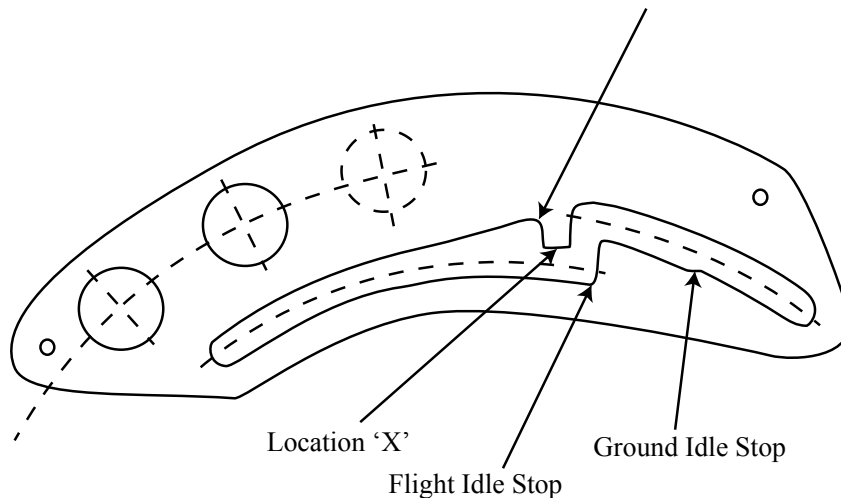


Figure 3
Power Lever Gate



Figure 4

Internal view of power lever, gate and latch

Asymmetric use of beta power

Experienced Dornier 328 pilots and training pilots commented that they believed selection of one engine in the beta range with the other in flight idle would give rise to difficulty controlling the aircraft in yaw. The Flight Manual makes no provision for such operations.

Previous incidents

In February 1999, a Dornier 328 overran the end of Runway 29 at Genoa Airport, Italy, and came to rest partially submerged in the sea beyond the runway end. There were four fatalities amongst the 31 passengers and crew on board, and two of the occupants sustained serious injuries. The Italian Ministry of Infrastructures and Transport carried out an investigation into the accident and concluded:

'the accident..., was caused by the pilot being unable to move the power levers from the flight idle position to the ground idle position and then to the reverse thrust position. The power levers remaining in the flight idle position meant that the propellers kept turning which prevented the aircraft from slowing sufficiently and frustrated the use of the brakes and emergency brake.'

The report made several Safety Recommendations, including:

'To the Dornier-Fairchild company: if this has not already been done, define an emergency procedure allowing the crew to manage incidents where it is repeatedly impossible to move the power levers from the flight idle position during the period of travel after landing.'

In July 2004, a Dornier 328 crew rejected a takeoff at Glasgow Airport when they found that the left engine power lever would not move forwards through the Flight Idle position. Subsequently, it would not move rearwards from the position. The CAA investigation stated:

'Upon restoring the levers into the normal range, the power lever sometimes cannot be moved past flight idle. Rectification of this situation is usually achieved by lubricating the cam.'

The inspection and lubrication interval for the power lever cam followers was reduced from 4,000 to 2,000 flight hours. The report concluded that:

'the hazard is adequately controlled by the actions stated above.'

Earlier, in January 2004, a Dornier 328 crew at London City Airport experienced difficulty moving the No 1 power lever, finding that it could not be moved from the Flight Idle position during an attempt to take off. The reporter noted that the latch on the No 1 power lever was sticking in the up position, but could be forced downwards, allowing forward power lever movement. The operator reported that, following cleaning and lubrication, the lever operated correctly. The lever, latch, and cam should be cleaned, inspected, and lubricated every 4,000 hours, and the operator reported that this interval was satisfactory. The report concluded that:

'the hazard is adequately controlled by existing requirements, procedures and documentation.'

In February 2005, a Dornier 328 crew carried out a baulked landing at Southampton Airport, when the co-pilot (who was pilot flying) found that he could not select ground idle after touchdown. The baulked landing

and subsequent visual circuit and landing were without incident. The CAA report stated that:

'the airline has introduced a safety instruction detailing how to carry out the correct procedure with the throttle... based on Dornier service information leaflet SI-328-00-067.'

The report concluded that:

'the hazard is adequately controlled by existing requirements, procedures and documentation.'

Other pilots' accounts

Experienced Dornier 328 pilots and training captains, including one with test flying experience, were interviewed in the course of the AAIB investigation. They were all aware of the potential for the power levers to jam, and a number of them had experienced this themselves. In each of these cases, however, further attempts to achieve the Ground Idle range had been successful.

AAIB evaluation of the power levers and latches

An AAIB Inspector, with previous experience on turboprop aircraft, evaluated the operation of the power levers and latches from both pilot seats. With the aircraft stationary and the engines shut down, the power levers were moved as though after landing. On one of ten attempts from the left seat, it was found impossible to disengage one of the latches.

Further evaluation of the manner of operation of the latches indicated that with rearwards pressure applied to the power lever, considerable upwards pressure was necessary to operate the latch. If the latch was forced upwards in this manner, the power lever was caused to move slightly forwards as the latch was operated. The

effort required to force the latch up was considerable, and was not achievable with the palm of the hand resting lightly on the power levers and the tips of the fingers operating the latch.

Operator's documentation and crew training

Both pilots had undertaken ground school training with an established UK operator of the aircraft type. During this training, they had been informed that difficulties had been experienced by pilots attempting to select the power levers below the flight idle position after landing. They had been told that the appropriate technique in this situation was to advance the power levers again, then retard them to the flight idle stop, before making a further attempt to disengage the latches.

After this incident the operator provided additional training to all crews to familiarize them with the circumstances of the event and to re-brief them on the contents of Dornier 328 Service Information Leaflet SI-328-00-067. Items discussed were the event background, the Service Information Leaflet contents and the balked landing procedure. This was followed by a practical demonstration of power lever / reverse latch operation whilst the aircraft was on the stand. This has also now been emphasized in the simulator training syllabus.

AAIB Special Bulletin S7/2006

As a result of these concerns, in August 2006 the AAIB published a Special Bulletin, S7/2006, publicising the incident to TF-CSB. The bulletin contained the following Safety Recommendation:

Safety Recommendation 2006-104

It is recommended that Avcraft Aerospace GmbH i.I advise all operators of Dornier 328

turboprop aircraft to detail procedures, and provide adequate training, to ensure that their pilots are able to act appropriately if the beta control range on the power levers cannot be selected after landing.

The CAA responded to this Safety Recommendation as follows:

'This Recommendation is not addressed to the CAA. However, the recommendation has been acted upon by the CAA and Inspectors, assigned to the UK companies operating Do328 aircraft, have been made fully aware of the issue and will be discussing the incident with the companies as necessary.'

In December 2006 the Type Certificate holder published Temporary Revision 20-006 to the Airplane Operating Manual, which introduced an option of a balked landing, to be carried out at the pilot's discretion, if a power setting below Flight Idle could not be achieved. This was supported by the re-issue of Flight Ops Information FOI-328-76-01 on 19 December 2006.

Protection of the overrun area

The aircraft came to rest 350 metres beyond the end of the runway. CAP 168 *'Licensing of Aerodromes'* defines a *'Runway Strip'* as follows:

'A runway strip is an area enclosing a runway and any associated stopway. Its purpose is to... reduce the risk of damage to an aeroplane running off the runway by providing a graded area which meets specified longitudinal and transverse slopes, and bearing strength requirements...'

CAP 168 also requires the provision of Runway End Safety Areas (RESAs), which are defined as:

'intended to minimise risks to aircraft and their occupants when an aeroplane overruns or undershoots a runway'.

Runway 34 at Aberdeen is a Code 4D runway, according to the categorization in CAP 168. Thus the runway strip extends 60 metres beyond the runway end. The RESA is required to extend 90 metres, and recommended to extend 240 metres, beyond the runway end, although CAP 168 instructs aerodrome operators to provide RESAs of length appropriate to the runway and operations on it, based upon assessment of overrun risk and other factors.

The RESA at the end of Runway 34 is 240 metres long, and the aircraft came to rest 110 metres beyond its end in an area where no protection for overrunning aircraft is required or specifically recommended.

Engineering investigation

Description of significant components

The aircraft type is powered by two Pratt and Whitney (Canada) PW 119B engines driving Hartzell six-bladed, composite, reversible-pitch propellers. The aircraft in question was also equipped with automatic lift spoilers, although not all Dornier 328s are so fitted. Each engine/propeller combination, or powerplant, is controlled via a power lever and a condition lever, which are mounted conventionally on a console between the two flight crew seats. These levers are connected to the propeller and fuel control units in the nacelles by a system of cables running in conduits and passing over pulleys. The power levers are offset towards the left flight crew seat, the condition levers towards the right. During flight each power lever operates between the

geometric flight idle position and maximum power position. Latch levers on the forward face of each power lever must be raised to enable selection of the beta (ground idle) propeller range. Once these latches are raised, the power levers are free to move further aft, commanding a progressively lower blade pitch angle. Further movement aft causes the levers to reach the ground idle position. Aft movement beyond the ground idle position increases power, providing reverse thrust. This movement into the reverse thrust range compresses a spring within the quadrant which provides tactile information to the pilot.

Undesired movement of each power lever from the flight idle position to the ground idle position is prevented by contact between a roller on the lever mechanism and a fixed stop in the console (see Figures 4 and 5). Each roller is mounted on a pin, which in turn is attached to a fitting on a vertical rod mounted within its power lever. Each roller moves aft within a curved track as its power lever is moved backwards, until the flight idle stop is encountered. Raising the latch lever against spring pressure lifts the rod, which raises the roller clear of the flight idle stop. This allows the roller and hence the power lever to move further aft towards the reverse position, the roller travelling in a curved track having greater radius than that of the track within the flight range forward of the flight idle stop position.

The two sections of curved track and the flight idle stop at each power lever location each take the form of a continuous shaped cut-out in one of a pair of titanium alloy plates orientated in a vertical and longitudinal plane. Each roller is manufactured from a bronze alloy and moves within its cut-out forming the curved tracks and the relevant flight idle stop.

The latch levers are positioned forward of and below

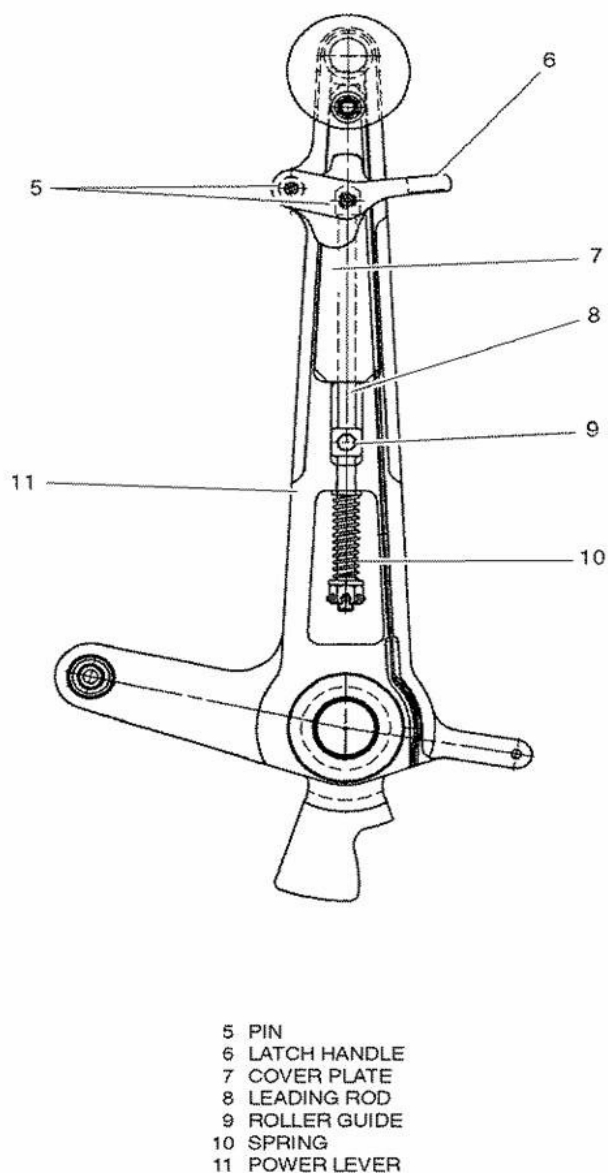


Figure 5

Power lever assembly

the roll handles of the power levers such that they can be grasped by the fingers whilst the palm of the hand rests comfortably on the lever.

Initial examination

No obvious damage to the aircraft was evident. Tyre skid markings consistent with heavy braking on all four main-wheels were evident, beginning towards the over-run end of the paved surface. These began

close to the centre-line and deviated to the right before deviating progressively to the left. They indicated that the aircraft left the paved surface close to the junction of Runway 34 with Taxiway W by the Runway 19 threshold, travelling at an angle to the left of the centreline. Wheel marks on the grass show that the aircraft then turned back until it was travelling parallel with the runway, but significantly to the left of the extended centreline.

Detailed technical evaluation

Following the in situ examination by the AAIB Engineering Inspector, the aircraft was towed to a hangar for detailed examination. Particular attention was given to the operation of the engine power and reverse latch lever systems. No evidence of damage or malfunctioning of the engine and propeller controls was found. Slight damage to the aircraft wheels was detected during a hard landing check; this precluded taxiing before replacement wheels could be sourced and prevented functional testing of the wheel brake system. It was noted, however, that the brake system was free from hydraulic leaks and interrogation of recorded data in the aircraft maintenance computer showed that very high temperatures were reached by all four brake units during the landing roll, consistent with normal functioning of the brakes.

Engine ground runs were carried out, during which all propeller functions were operated a number of times. In all cases correct functioning occurred. Finally the condition of the reverse latch rollers within the console was checked in accordance with the requirements in the Aircraft Maintenance Manual (AMM). Neither defects nor evidence of significant wear was found.

This particular aircraft was equipped with spoilers which could only be deployed after a time delay of four

seconds, when both power levers were at or below the flight idle position. Examination of the torque variations recorded on the FDR during the ground roll confirmed that the thrust levers were exercised a number of times. Thus they were not allowed to dwell at a flight idle for sufficiently long to allow the required time delay to elapse. Each forward lever movement cancelled the cycle and required the delay time interval to begin again after the levers were retarded.

From the above examination and the assessment of data, it was concluded that the wheel brakes operated correctly, the propellers did not enter the beta range, and the spoilers, although functioning correctly, did not deploy because the power levers did not remain in flight idle for sufficiently long each time they were retarded.

General comments on power lever and latch design

A fully serviceable mechanical engine/propeller control system on the type operates satisfactorily, from a purely mechanical point of view, provided all components are undamaged and no significant wear is present in any of the parts. There was little wear of the profiled plates in the console and the work-hardening characteristics of titanium alloy from which they are manufactured, coupled with the material properties of the soft bronze alloy of the latch rollers which operate in contact with the plates, ensure that the rollers cannot inflict significant wear damage on the plates. The inspection requirement to examine the soft roller material for damage or wear seems to provide a suitable yardstick for controlling and rectifying the overall wear of the plate/roller combination.

Nevertheless the above, difficulties in achieving selection of beta range after landing have been experienced, of which this event is an example. Such problems may occur if the precise angular positioning

of the levers is not correct at the time when attempts are made to lift the latches. Incorrect positioning is thought to be facilitated by ergonomic features of the power lever/latch lever combination. These are accentuated by the fairly high degree of friction in the cable/conduit systems that connect the power levers to the propeller and fuel control units in the nacelles.

The power levers (Figure 5) have their middle portions machined away to form a slot which accommodates the latch operating mechanism. This modifies the lever structures from acting as beams in bending to resembling portal frames, significantly reducing their bending stiffness and introducing a slight spring effect in their operation. The friction in the operating systems, combined with the relatively low bending stiffness of the power levers, can significantly mask the tactile feel of the contact between the rollers and the flight idle stop detents as the levers are retarded.

Ergonomic issues

Considering the behaviour of one lever in isolation, correct positioning at the flight idle angle allows the latch to be lifted using the designed finger force, ie solely overcoming that created by the latch return spring. Rapid, firm movement of the lever aft to the stop, however, may result in slight flexing of both the lever and parts of the console structure which can result in movement of the cable within the conduit occurring slightly beyond the position achieved if more gentle movement occurs. This over-travel may be locked into the cable by static friction effects within the conduit and the cable/pulley system.

If the latch is then lifted, the roller must travel over a slight projection created by the curved profile of the flight idle stop. The necessary forward movement of the lever to allow this is resisted by the friction in the cable

causing the fitting to which the roller pin is attached to bear firmly on the forward face of the locating slot in the power lever. Friction created by this contact adds to the spring force resisting the lifting of the latch. Active backward hand force on the lever, if present, further increases the force required to lift the latch, by way of the same geometric effect; the magnitude of the force increase being approximately in proportion to the magnitude of this backward hand force.

Should, however, the lever be inadvertently positioned slightly forward of the correct flight idle angle, the latch will be baulked by the gate plate and will be impossible to lift. If the lever is significantly further forward of this baulk position, the latch may be easily lifted up to approximately $\frac{2}{3}$ of normal travel into a 'false detent', resisted solely by normal spring force. This 'false detent' is created by a recess in the upper edge of the track significantly forward of the flight idle position. Backward movement of the power lever from the 'false detent' to the flight idle position cannot take place without releasing the relevant latch lever(s) allowing the roller(s) to descend under spring pressure. This situation has been addressed in the manufacturer's bulletin reference SI-328-76-048 issued on 5 November 1998. For this situation to arise, the power levers must be positioned some distance forward of the flight idle position, and it is not considered that this condition occurred in this incident. Recorded flight data indicates that the engines were at flight idle several times after touchdown.

With the lever positioned even further forward, applying upward pressure on the latch imposes an aft component of force on the power lever as a result of the latch roller bearing on a sloping contact face of the cut-out, thereby reducing the normal hand force (brought about by the friction in cables, pulleys and in the cable/

conduit system) necessary to retard the lever. At the same time the latch moves up against a force slightly greater than the spring force provided the power lever is moved steadily aft. Under these conditions, the latch lever will eventually move up some $\frac{2}{3}$ of full travel and be unable to move further whilst the roller will eventually reach the false detent, under lower than normal backward hand force on the power lever and again, roller and power lever will be unable to move further aft until the latch lever is released.

Only by correctly positioning the power levers at a precise angle, ie in light contact with the flight idle stops, will the fingers be able to operate the latches solely against the spring pressure in order to move smoothly into the beta range and thence into reverse.

The stiffness of power lever movement created by the friction of the cables may cause uneven and slightly different movement of the two power levers, leading to potential for slight throttle stagger during the retarding process. This may allow one latch roller to come into firm contact with the flight idle stop whilst the other lever may be correctly positioned only in light contact with the stop, ensuring minimum latch movement force. Thus a significant difference in lifting force between the two latches would be evident to the pilot. Alternatively, with both power levers slightly further forward and staggered, one may be sufficiently far forward for the track to completely baulk upward movement of the latch roller whilst the other latch lifts freely being only constrained by its return spring. Easy upward movement of one latch accompanied by stiff operation or complete baulking of the accompanying lever may result, for the pilot, in confusion about the freedom of movement of the reverse system in general.

These difficulties may seem at first sight to be unlikely

to cause an operating problem when viewed in isolation. However, immediately following an approach and touchdown, with the runway end rapidly approaching, the precision of the actions required to place both propellers in reverse at the same time makes this a more demanding task. The required sequence involves delicate, accurate movement of levers whose operation is fairly stiff, (accentuated for a pilot in the right-hand seat by the offset of the power levers positioning them further from his body) followed, often rapidly, by lifting of the latches. Anticipation of the need for the latter might result in premature latch lifting attempts or attempts made when the power levers are not precisely positioned. This possibility is assisted by ergonomic design features of the latch levers, since they fall easily beneath the fingers of a hand which is placed on the power levers and orientated in the optimum position to retard them. It could become an easy and natural process to squeeze the latch levers as the power is retarded. Failure to ensure that both levers are positioned gently against the aft flight idle stop before latch lifting is attempted can lead to stiff operation, asymmetry of latch stiffness or baulking of one or both latches.

These effects can create the perception that jamming is occurring, even when it is not, or actual jamming of one or both latches can occur as a result of a variety of these scenarios.

Alternative Design Approaches

A reverse lever and interlock arrangement is commonly found on turbo-fan powered aircraft. To enable reverse operation the pilot must retard the thrust levers fully before transferring his hand to the dedicated reverse levers. These are positioned as part of the thrust levers but cannot be reached without difficulty until the thrust levers are fully retarded. Once the thrust levers are fully aft, the reverse levers can be grasped and

moved, usually to a detent position where an interlock prevents their further movement until the reversing hardware is correctly positioned for reverse operation and the interlock is released. Thrust can thus only be increased once the thrust reversing mechanisms are in place. Deliberate difficulty in attempting a continuous movement through idle thrust to reverse is created by the designed-in need to change hand position during the process.

Although the process of reverse selection in this arrangement is rendered more complicated, the chances of accidental or premature reverse selection are much lower.

Such an arrangement is uncommon on turbo-prop types. Nonetheless, a design change to achieve re-orientation, or different sizing of the latch levers to make it necessary to reposition the hand, would reduce the possibility of jamming through incorrect lever sequencing. Careful design of the position and orientation of the latch levers should enable reverse operation to be appropriately controlled once the power lever has passed into the latch release position.

Examination of other turbo-prop aircraft types

The power lever controls and reversing arrangements of two other aircraft types were examined as part of this investigation.

Both aircraft types were types powered by a pair of three spool Pratt and Whitney Canada turbo-prop engines of the PW 119/125 family, having generally similar requirements of their control systems to those of the Dornier 328 aircraft. The first type was initially certificated in North America whilst the second was initially certificated in Europe.

The first type examined had FADEC⁵ and electrically controlled engine and propeller functioning, obviating the need for lengthy mechanical interconnections between power levers and the engine nacelles. Significant friction was thus not present within the operating system other than that created by the manually adjusted friction control on the console. The power levers were notably stiffer in bending than those on the Dornier 328. Operation of the levers in a retarding sense thus occurred with good tactile feel. This enabled the flight idle stops to be detected easily when the power levers were symmetrically moved aft to that position. In a similar manner to the Dornier 328, finger operated latches on each power lever could only be lifted when the power levers were correctly placed at the fully aft position of the forward range (ie flight idle).

In contrast with the arrangement on the Dornier, however, the positioning of the hand on the levers to control engine power and to retard the levers during landing, differed significantly from that required to lift the latches. The latches are positioned directly below the cylindrically shaped power lever roll grips and cannot be properly manipulated by the pilot unless the hand is repositioned. The arrangement thus ensures that any tendency to baulking created by applying simultaneous force to both the levers and the latches is minimised. There is little scope for doubt when the levers are at the flight idle position, ready for the latches to be lifted and the levers to be moved further aft into reverse.

The other aircraft examined had power lever functions connected mechanically to the fuel and propeller control units in the nacelles. Lever friction was thus high and of similar magnitude to that encountered in the Dornier 328 system. No controllable friction device was therefore necessary or fitted.

Footnote

⁵ Full Authority Digital Engine Control (FADEC).

In the case of the second aircraft type, however, the in-flight power of each engine was controlled by a dedicated lever, the rearmost position of which coincided with flight idle. Low pitch operation and reversing of each propeller was achieved by use of a separate lever mounted on each power lever, in a manner somewhat similar to that found on turbofan aircraft described previously. These reversing levers were mechanically baulked at all power lever angles forward of flight idle. Operation of each reversing lever required the corresponding power lever to be moved to the aft stop, released and the hand moved physically forward to grasp the roll handles of the reverse levers. During examination on the ground one negative aspect was noted. If the reverse levers were pulled rearwards when the power lever was forward of the flight idle geometric position, although the reverse lever could not initially move, a component of the hand force created by pulling it against the baulking action reacted upon the power lever, driving it rearwards. This enabled it to reach the flight idle position at which point sustained force on the reversing lever caused it to move into the reversing range.

Both the above arrangements provide a distinct division between power lever movement and, either movement of the lever into the reverse range, or operation in that range. In doing so they provide the necessary positive safeguards against inadvertent reverse operation in flight. At the same time they also largely prevent simultaneous attempts at movement of both levers together during landing, which can lead to baulking.

The Dornier 328 differs from either of these two arrangements in having the latch levers positioned where they can readily be pulled upon during aft power lever movement.

Analysis

There have been a number of events in which pilots have experienced difficulties in selecting ground idle after landing, or other difficulties in moving Dornier 328 power levers. Actions taken as a consequence of these events have been to alter the maintenance procedure for the power levers (on the assumption that wear and/or lubrication is the cause) or to instruct pilots to alter their technique.

Pilots have also been trained to deal with such a problem after landing, with one UK operator carrying out simulator training of its crews to enable them to carry out a baulked landing (effectively, a go-around after the aircraft has touched down). This procedure acknowledges that, if the power levers are not retarded to ground idle soon after touchdown, it may not be possible to stop the aircraft. Factors giving rise to this difficulty include the relatively high thrust of the Dornier 328's powerplants, the rapid rate at which it is progressing along the runway soon after landing, and the relatively limited braking capacity required by turbopropeller aircraft in general⁶. The operator of TF-CSB had not carried out this training, but its operations manual did instruct pilots how to deal with a power lever jam.

The instructions in the operations manual, to advance and then retard the power levers in order to resolve a jam, appear, at first sight, to be reasonable. However, there is a tacit assumption that this procedure will be effective, the jam will be cleared, and there will be sufficient runway remaining on which to stop the aircraft. On a limiting runway, this may well not be the case, and if a crew find it necessary to carry out these actions (as did

the crew of TF-CSB), repeatedly advancing the power levers will add energy to the aircraft on each attempt, making an overrun more likely.

The runway at Aberdeen is longer than many on which the aircraft type typically operates, yet the aircraft came to rest beyond the end of the RESA. It was fortunate that this additional area also met the requirements of a RESA, although it was not declared as such. Had the terrain or obstacles in this area been less benign, the outcome could have been very much more serious.

Following the accident in Genoa, two amendments were made to the airplane operating manual, one of which identified that it was possible to move the power levers aft, with the latches lifted, until the latch cams were in 'Location X' (Figure 3). Whilst there is no doubt that this position is achievable, it is also possible that the investigation into that accident did not identify the difficulties found in the course of this investigation, and that the difficulties experienced by pilots centre, not around placing the cams into 'Location X', but around the friction and cable forces. Thus, whilst technically accurate, the second amendment to the airplane flight manual may have been based upon a false assumption of cause. Therefore the following additional Safety Recommendation is made to the Type Certificate holder's National Airworthiness Authority, the Luftfahrt-Bundesamt (LBA), to minimise the likelihood of a further, similar, accident:

Safety Recommendation 2007-103

The Luftfahrt-Bundesamt should ensure that a training programme, fully alerting Dornier 328 crews to the potential for restricted movement and the optimum operation of the lever/latch combination, and detailing appropriate operational procedures, be developed and

Footnote

⁶ The Dornier 328 aircraft meets the relevant certification requirements.

mandated for all operators in Europe, and through liaison with all relevant National Aviation Authorities, make this information available to all operators of the Dornier 328 worldwide.

In the longer term, the design features which allow the fingers of an average hand to bear comfortably on the reversing latches, whilst the palm of the hand is positioned in the optimum orientation for power regulation and reduction, should be eliminated. Therefore the following Safety Recommendation is also made:

Safety Recommendation 2007-104

The European Aviation Safety Authority should require the Dornier 328 Type Certificate holder to re-design the power lever/beta/reverse latch system to improve the present arrangement.