Fokker F27 Mk 500 Friendship, G-JEAH, 4 August 1995

AAIB Bulletin No: 4/96 Ref: EW/C95/8/1 Category: 1.1

Aircraft type and registration: Fokker F27 Mk 500 Friendship,G-JEAH

No & Type of Engines: 2 Rolls-Royce Dart 532-7 turbopropengines

Year of Manufacture: 1986

Date & Time (UTC): 4 August 1995 at 0709 hrs

Location: Belfast City Airport

Type of Flight: Public Transport

Persons on Board: Crew - 4 Passengers - 18

Injuries: Crew - Nil Passengers - Nil

Nature of Damage: Turbine burnout on both engines

Commander's Licence: Airline Transport Pilot's Licence

Commander's Age: 58 years

Commander's Flying Experience: 8,410 hours (of which 2,788were on type)

Last 90 days - 204 hours
Last 28 days - 77 hours

Information Source: AAIB Field Investigation

History of the Flight

The aircraft, using callsign JY 1730, took off from Leeds BradfordAirport at 0605 hrs for a scheduled flight to Belfast City Airportwith the commander as the handling pilot. Take off and climb werenormal and the commander established in the cruise at Flight Level(FL) 145 at an indicated airspeed of 185 kt; no problemswere recorded in the technical log or noted by the crew duringthe flight.

Approximately 45 nm from Belfast, where Runway 04 was in use,the crew requested and were given initial descent clearance. Ashe commenced his descent, the commander asked the first officerto select the high pressure cock (HPC) levers to 'Open'. However,the first officer had just recently completed his line trainingand was slightly unsure of the procedure, and so the commandertook the opportunity to demonstrate the correct way to selectthe HPC levers to 'Open'; this action was corroborated by evidencefrom the CVR. The other descent checks were completed by the firstofficer and monitored by the commander. As the aircraft levelledat FL 120, JY 1730 was transferred to Aldergrove ATC who theninformed the crew that Runway 22 was now in use at Belfast CityAirport. The crew had already briefed for an approach to Runway04 and so the commander then rebriefed for the new runway. Overthe next few minutes, the aircraft was cleared for a further descentand transferred to Belfast City ATC. Then, once JY 1730 was clearedto an altitude, the commander asked the first officer for theapproach checks. According to the CVR evidence most of these checkswere completed but there was no mention of the HPC levers duringthis time; in the company checklist the HPC check is requiredbetween those for the Decision Height and the Pneumatic Pressures.The CVR reflects a conversation about Decision Height and thencovers the Pneumatic Pressure check. However, the first officerrecalled pushing the HPC levers to 'Lockout' and the commanderrecalled monitoring this action. Subsequently, the commander interceptedthe ILS at approximately 13 nm from touchdown and commenced hisfinal approach. During this time the first officer completed thelanding checks and these included a response from the commanderthat he saw 'Two Blues', which indicated to him that the cruiselocks had withdrawn; this call was clearly recorded on the CVR.Touchdown was at the normal landing point with Flap 40 selectedand at the correct speed; threshold speed had been assessed as95 kt. For landing, the weather was good with a surface wind of080°/05 kt and a temperature of 18°C.

After landing, the commander retarded the throttles and then selectedthe throttles to 'Ground Fine'. At this stage the priority forthe first officer was to monitor the lights relating to the propellerlocks and associated propeller pitch angles. He was immediatelyaware that the required 6 lights, comprising 2 Blues, 2 Ambers(indicating that the flight fine locks had been withdrawn) and2 Reds (indicating that the propellers had decreased through 18°pitch) were not all on; the 2 Ambers were on, but he was not certainthat any others had illuminated. He advised the commander wholooked for the 2 Red lights and confirmed that they were out.Additionally, the commander did not feel the normal retardation,or hear the normal propeller noise, and so he reselected 'GroundFine' again. This still had no effect on the propellers and so,after one further attempt to select "Ground Fine", heselected 'Gust Lock', but again this had no apparent effect onthe propellers. G-JEAH was still at approximately 80 kt and thecommander commenced braking; he also noted that both TGTs wereclose to 950°C but did not notice the propeller RPMs. Hethen closed both HPC levers to 'Shut' and brought the aircraftto rest on the runway using moderate braking. Shortly after G-JEAHstopped, a crewmember of another aircraft called JY 1730 to reportflames coming from the left engine of G-JEAH; the ATC controllerheard this call and immediately alerted the Airport Fire Service.Within the cockpit, the commander looked and could see a littlesmoke but no fire from the left engine. The first officer lookedto the right and could also see some smoke but could not identifythe source. There were no cockpit fire warnings, but the commanderselected the HPC levers to 'Feather', pressed the 'Feather Buttons'and fired 2 fire bottles into each engine. By this stage, theFire Section was on scene and saw fire coming from both engineexhausts; the fires were quickly extinguished by the Fire Section.The commander had already called one of the cabin attendants tothe cockpit to brief her and, because the situation was undercontrol, decided not to order an emergency evacuation. The passengersthen disembarked through the normal exit using a ladder providedby the Fire Section.

After disembarking from the aircraft, one of the passengers tooka series of photographs showing the left side of the aircraft.The first of these photographs shows the left propeller in thefeathered position; subsequent photos show the propeller backout of feather.

The F27 Rolls Royce Dart powerplant

The 4 blade Rotol propeller can be varied in pitch from 0°(ground fine) to 87° (feather). During normal flight, engine(and propeller) RPM is maintained at the selected value by a conventionalhydromechanical constant speed unit (CSU), from a maximum enginespeed of 15,000 RPM to a minimum of 11,000 RPM. The propellerincorporates two pitch locks: a *cruise lock* at 32°propeller pitch, and a *flight fine* lock at 20°. Thepurpose of the cruise locks is to provide protection in the eventof a fault causing a single propeller to fine off, which, at trueairspeeds in excess of 265 kt, could create asymmetric loads orpropeller overspeeds capable of hazarding the aircraft. The flightfine pitch locks prevent the propeller pitch moving inadvertentlybelow the flight fine position, and are withdrawn only when theaircraft is on the ground. Engagement and disengagement of thecruise locks is automatic when the HPC levers are set to 'Open',and occurs as the propeller passes through 34° pitch, sensedby hub switches built into each propeller; the cruise locks canalso be withdrawn manually, by selecting the HPC levers to "Lockout".Removal of the fine pitch lock is achieved by selecting g*roundfine* pitch on either power lever, or engaging the gust locks.

Because the Rolls Royce Dart is a single-shaft engine, the massflow of air through the turbine is proportional to propeller speed.It is therefore essential that propeller pitch is maintained ata suitably low setting until the engine has spooled up adequately,otherwise RPM stagnation and associated over-fuelling will causerapid turbine burnout. In practice, this dependency means thatif the propellers are at the flight fine pitch setting and theaircraft is static on the ground, or at low speed, then even withthe power levers fully retarded the RPM will be too low for thescheduled fuel flow, causing the TGT to rise progressively beforestabilising at an abnormally high level, albeit one which is notlikely to cause damage to the turbines; if the throttles shouldbe advanced even moderately under these conditions, however, turbineburnout will occur in a matter of seconds. Similarly, if a propelleris on the cruise lock and the airspeed is allowed to decay withthe power lever retarded, for example should the propeller hangon the cruise lock during an approach to land, then the RPM onthat engine will decay below normal and the TGT will rise as airspeedreduces; if the throttles are then opened rapidly, overfuellingand immediate burnout of the affected turbine will occur.

For reasons which are explained later, a failure of the 34°hub switch contacts on a single propeller will prevent both cruiselocks from withdrawing, leading potentially to a double engineburnout. Such an event could have critical consequences shouldit occur whilst airborne, for example during an overshoot. Forthis reason, the Flight Manual calls for selection of HPC leversto 'Lockout' (manual override) for approach, take off, and climb.

Propeller control system

Compared with modern multi-shaft engines fitted with mechanicallysimple propellers, the pitch control system on Rotol propellersfitted to the single shaft Dart engines is complex. Both the CSUcontrol and safety lock systems are electro-hydraulic, using engineoil. The CSU pump output pressure is nominally 600 psi, butwhenever the propeller pitch is above 34◦and the cruise locks are engaged, the oil pressure in the *finepitch* side of the CSU control circuit is reduced to 180 psiby an hydraulic servo valve (the fine pitch relief valve); below34◦ pitch, the *fine pitch* oilpressure is restored to the full 600 psi. The *course pitch*supply to the propeller is maintained at 600 psi at all times.

Pitch lock mechanism

The pitch lock comprises a spring collet with a series of baulkblocks mounted on spring fingers, see item "D" in Figure1, which intrude into the path of the internally stepped sleeve("E") formed on the forward side of the pitch changepiston. An internal support sleeve "G", which has threesteps machined onto its outer diameter, slides inside the lockcollar such that the stepped section engages the inside of thebaulk collar, limiting the extent to which the lock fingers cancollapse inward. The support sleeve has three operating positions:

i) Cruise lock engaged

ii) Flight fine lock only engaged

iii) Neither lock engaged

A large spring pushes the support sleeve toward the fully engagedposition at all times. Withdrawal of the sleeve to the secondand third stage positions is achieved by two independent hydraulicpistons: the cruise lock withdrawal piston ("F"), andthe flight fine pitch lock withdrawal piston ("H") respectively.(The electro-hydraulic system controlling the operation of thesepistons is described in detail later.)

With the propeller at a pitch setting above 34°,as shown in Figure 1, the lock fingers are extended fully andthe internal support sleeve is fully engaged inside the springcollar. In this condition, the cruise lock is engaged. Shouldthe propeller pitch fine off with the cruise lock engaged, theouter end of the pitch change piston sleeve "E" wouldabut the lock fingers, as shown in Figure 2, preventing any furtherreduction of pitch. In this condition, the propeller is (hung)on the cruise lock. It should be noted that without the supportprovided by the internal support sleeve, the inward thrust developedacross the chamfered interface between the piston sleeve and thelock fingers (see enlarged view in Figure 2) would flex the fingersinward and allow the piston sleeve to override the lock collar.

Withdrawal of the cruise lock is achieved by moving the cruiselock withdrawal piston ("F") to its fullest extent,pushing the internal support sleeve forward to the second stageposition and freeing the lock fingers to collapse inward as faras the second step on the support sleeve. The pitch change pistoncan then override the lock collar and reduce the blade pitch backto the point where the internal shoulder on the piston sleevecomes into contact with the lock collar, as shown in Figure 3:this is the *flight fine* stop position.

Withdrawal of the flight fine lock is achieved by movement ofthe flight fine lock withdrawal piston ("H"), whichdraws back the support sleeve to the third stage position, freeingthe lock collar to collapse fully. The internal step on the pistonsleeve can then override the lock fingers, and the propeller pitchcan move fully back to ground fine (zero pitch), as shown in Figure 4.

Pitch lock control and indicating systems

The supply of hydraulic oil to the pitch lock withdrawal pistonsis controlled primarily by solenoid valves signalled by a systemof microswitches and/or latching relays, the circuit design ofwhich provides the appropriate control logic. In broad terms,the circuits controlling the operation of each pair of locks (iethe left/right flight fine locks, and the left/right cruise locks)are arranged in series across the aircraft, ie the condition forlock removal must be met on both engines before the logic requirementsfor lock withdrawal are met, thus protecting against asymmetricconditions.

Independent comparators in the cruise lock and flight fine lockcontrol circuits monitor the electrical integrity of the solenoidsand relay windings, and will illuminate a warning light on theflight deck to indicate an anomalous (unsafe) condition of therelevant lock circuit should a fault be detected; the crew canthen isolate the affected circuit using either the *cruise lockisolate* or *flight fine lock isolate* switch, as appropriate.The cruise locks can be removed at any time, even with the cruiselock circuit electrically isolated, by placing the HPC leversinto the "Lockout" position, which invokes a hydro-mechanicaloverride system to *manually* remove the locks.

Cruise lock control

In normal circumstances, the cruise locks engage automaticallyas the propeller pitch increases through 34◦,and withdraw again when the propeller pitch decreases below 34◦.Propeller blade angle is sensed on each propeller by a pair ofhub switches comprising carbon brush contacts connected via acam linkage to the blade root, and which move into contact witha slip ring mounted on the reduction gearbox housing as the bladeangle reduces through 34◦, (Figures 1to 4 show the 34◦ hub switch in schematicform.) Because the hub switches *make* at a blade angle 2◦above the cruise lock setting, the locks will normally withdrawslightly in advance of the blade reaching the actual lock position.

Figure 5is a schematic circuit diagram of the propeller controland indicating systems. Those circuits relating to cruise lockoperation are coloured blue. When both left and right propellerhub switch contacts have closed, the logic requirement for cruiselock withdrawal is met and both cruise lock withdrawal solenoidsare activated, porting hydraulic oil at 600 psi to the finepitch relief servo valve (not shown in the diagrams). Operationof this valve has two separate functions:

i) it causes the pressure in the fine pitch oil galleries to revertfrom 180 psi back to the full CSU pump output pressure of600 psi, and

ii) it closes off a drain (vent) line connected to the sensingchamber of a pressure switch (identified as the *cruise lock"unlocked" pressure switch* in Figure 5, and discussedin more detail later under the heading "Cruise lock indicatingsystem").

The increase in pressure within the fine pitch oil gallery from180 to 600 psi causes the spring biased staging valve (item"J" in Figure 1) to move forward against its bias spring,porting oil at 600 psi to the dual bodied cruise lock withdrawalpiston("F"), which moves fully forward against its stop,moving the internal support sleeve "G" to the secondstage position and withdrawing the cruise lock.

It can be seen from Figure 5that the cruise lock withdrawal solenoidsare connected in series, the *supply* being fed through theleft propeller hub switch and the *earth return* path beingprovided by the right hub switch. Therefore, a failure of eitherhub switch will inhibit cruise lock withdrawal on <u>both</u>propellers, leading potentially to a double engine burnout.

In order to provide a measure of redundancy and reduce the probabilityof failures of this kind, the 34◦ hubswitch on each propeller actually comprises two separate setsof brush contacts actuated by independent blades, which operatein parallel. Thus, provided at least one switch contact on eachpropeller *makes*, the logic requirement for lock withdrawalwill be met satisfactorily and the locks will withdraw. The *manualoverride* provides a further measure of safety. When the HPClevers are moved fully forward to the "Lockout" position,hydraulic oil at 600 psi is ported directly to the fine pitchrelief servo valve from the CSU, in lieu of the cruise lock removalsolenoid. (The flight manual requires "Lockout" to beselected for approach, take off, and climb.)

Cruise lock indicating system

Each cruise lock hydraulic circuit incorporates a pressure switch(the *cruise lock 'unlocked' pressure switch* in Figure 5),which operates a blue *cruise lock unlocked* light on theflight deck. The sensing chamber of the switch is connected to:

the *inlet* to the CSU controller pump (which is suppliedwith engine oil at 75 psi), via a restrictor, and

the 3rd oil line (the supply line to the flight fine lock removalpiston), via ports in the fine pitch valve servo spool.

Whenever the lock collar inner support sleeve("G") isfully engaged, ie the cruise locks are engaged, an annulus inthe bore of the sleeve connects the 3rd oil line to drain, seeFigure 1.

Thus, if:

the cruise lock is engaged (support sleeve annulus closed)

AND

the fine pitch relief valve is in the *cruise* position,

.....then the pressure switch will be vented to drain, the contactswill be open, and the blue light will remain out; closure of eitherthe annulus OR movement of the fine pitch relief valve spool willtherefore cause the blue light to come on.

Removal of the cruise locks, whether automatically (via the 34◦hub switches) or through use of the manual override (HPC leverto "Lockout"), will supply pressure to the fine pitchrelief servo valve, causing the valve spool to move and closeoff the connection to the 3rd oil line. The pressure in the sensingchamber of the switch will thus rise to 75 psi and causethe blue light to illuminate on the flight deck.

Should the spool of the fine pitch relief valve jam for any reason,the *fine pitch* control pressure supplied to pitch changepiston will remain at 180 psi; the staging valve thereforecannot move and consequently no oil will be ported to the cruiselock removal piston, the lock sleeve will not withdraw, and thecruise lock will remain engaged. In these circumstances, the ventpath to drain will be maintained and the blue light will not illuminate,correctly indicating that the lock is still engaged.

Should the fine pitch relief valve spool move correctly but thelock sleeve fail to withdraw for any reason, then the blue lightwill illuminate, giving a false indication on the flight deck.

In summary, a *false* blue light indication on the flightdeck could occur only if:

the fine pitch relief valve spool moves correctly

AND

the staging valve was jammed

OR

the PCU pump failed to provide sufficientoil pressure to break through the lock eg. due to leakage

OR

the cruise lock withdrawal piston or thesupport sleeve was jammed,

OR

one or more lock fingers was jammed or deformed

OR

there was a partial seizure of one or moreblade root bearings.

Flight fine lock control system

The flight fine lock control circuit is coloured amber inFigure 5. Operation of the flight fine pitch lock withdrawal mechanismis controlled primarily by a system of microswitches on the powerlever quadrants, with backup control being provided by a secondset of microswitches in the gust lock mechanical circuit. As withthe cruise lock electrical circuits, the signal and control systemcomponents are distributed between the two propellers in seriesmode: those associated with the left propeller control the *supply*side of the electrical circuit, and those associated withthe right propeller control the *earth* side of the circuit.The electrical signals from these switches control latching relaysand solenoid valves which, when all the logic requirements ofthe circuit have been met, send hydraulic oil at 600 psivia the 3rd oil line to the flight fine lock withdrawal piston.

Withdrawal of the flight fine locks is achieved by pulling either,or both, power levers fully back, through the lift/spring detentto the ground fine position. This results in closure of the gangedmicroswitch contacts "A1" and "A2", allowingcurrent to flow through the windings of the two lock removal solenoids(the supply being fed through "A1" and the earth returnpath being provided by "A2"); current also flows throughthe windings of the latching relays R1 and R2. Once latched, relaysR1 and R2 maintain the *supply* and *earth return* pathsto the lock withdrawal solenoids so that when the power leversare released and the spring returns them to the idle position(opening contacts A1 and A2 once again), the lock removal solenoidsremain energised. Movement of either power lever beyond the 14,000RPM position, ie sufficiently to cause contact B1 or B2 to open,will simultaneously break the circuit to the lock removal solenoidsand the latching relays, causing the lock withdrawal piston toretract and allowing the flight fine lock mechanism to re-engageas blade pitch increases past 20°.

A failure of either A1 or A2 to close for any reason would preventwithdrawal of both flight fine locks. Engagement of the gust lockmechanism, however, will cause the alternative pair of contactsC1 and C2 to close, thus making and latching the solenoid removalcircuit. The circuit will remain latched, as before, until eitherof the power levers is advanced to the 14,000 RPM position.

Flight fine lock indication

A pair of amber "flight fine unlocked" indicator lightson the flight deck are wired in parallel with the flight fineremoval solenoids. Although these comprise two separate lights,they actually provide a single indication that the electricalsupply to the flight fine lock withdrawal solenoids has been made.

Positive confirmation that each propeller has moved below theflight fine pitch lock is provided by separate and independentred indicator lights on the flight deck, which are supplied fromsupplementary hub switch contacts on each propeller, similar tothose which control cruise lock withdrawal, but which in thiscase close as the propeller pitch passes below 18◦.The 18◦ indicator light circuits arecoloured red inFigure 5.

Summary of propeller controls and indication

Operation of the cruise lock is solely automatic if the HPC leversare at 'Open', when the system relies on the hub switches to retractthe lock as the propeller pitch decreases through 34°. Amalfunction of the cruise lock withdrawal solenoids or relayswill cause an amber "unsafe" warning light to illuminateon the flight deck, and the *cruise lock* electrical systemcan be isolated by means of an isolate switch; however, a hubswitch failure will not be detected. The cruise lock can be retractedmanually by the selection of the HPC lever to "Lockout",regardless of the state of the electrical control circuit. Illuminationof a "Blue Light" indicates that the hydraulic system*demand* for cruise lock withdraw has been made on that propeller,and that the fine pitch relief valve spool has moved, increasingthe fine pitch control pressure to 600 psi; it does not indicatethat the locks have physically withdrawn, or that the blades havemoved below the lock position.

The flight fine pitch locks are operated manually by selectingeither or both power levers to "Ground Fine". Illuminationof the "Amber Lights" indicates that both flight finepitch locks have been demanded to withdraw. Illumination of a"Red Light" provides positive confirmation that theassociated propeller is below 18° pitch. Selection of gustlocks engaged (on the ground) provides an alternative means ofwithdrawing the flight fine pitch locks. Re-engagement of theflight fine pitch lock requires that one or other power leveris moved toward the *high power* end of the quadrant, toabout the 14,000 RPM position. A malfunction of the flight finelock withdrawal solenoids or relays will cause an amber "flightfine pitch lock unsafe" warning light to come on; the electricalsystem can then be isolated by means of an isolate switch.

Examination of the aircraft

Engines and propellers

Both engine exhaust ducts contained small fragments of debrisconsistent with a turbine burnout, but there were no externalindications of fire or excessive temperature affecting the nacellesor the external surfaces of the engines. Based on the amount ofdebris in the exhaust ducts, the right engine appeared to be slightlymore damaged than the left engine. Neither propeller would turnfreely, consistent with burnout debris jamming the turbine sectionsof the engines.

Because the propeller blades had been moved to feather immediatelyafter the incident, and then moved back out of feather again,it was not possible to determine the pitch of either propellerwhen the aircraft landed.

The control linkages connecting the power levers and HPC leversin the cockpit to their respective engine components were intact;the linkages operated freely, and the rigging was within limits.

The propellers were moved into feather without difficulty, andboth propellers removed. A visual inspection of each propeller,so far as this was possible, revealed nothing unusual except forexcessive wear of the 34◦ hub switchbrush contacts on the right propeller, both of which were wornbelow the limits specified by the manufacturer. [The worn brusheswould have increased significantly the probability of the righthub switches failing to close when blade pitch reduced through34°; such a condition would have prevented both cruise locksfrom withdrawing automatically, but moving the HPC levers to "Lockout"should still have effected withdrawal.]

Both engines were removed and replacement units installed on theaircraft. After replacement of the worn hub switch brushes onthe right propeller, both propellers were reinstalled. Post installationchecks revealed that one of the fuel trimmer switches in the cockpitwas defective and this was replaced, but no other abnormalitieswere noted.

Full (static) functional checks of both propellers were carriedout, in accordance with the maintenance schedule, during whichthe pitch change mechanisms and lock systems on both propellersfunctioned entirely satisfactorily. The engines were then startedand full functional checks of both engines and propellers werecarried out per the maintenance schedule; again, both propellerpitch change and lock systems operated entirely satisfactorily.The aircraft was then returned to service.

During the initial stages of the first take off following theengine change, the flight fine pitch lock unsafe warning lightilluminated and remained on. (Transient illumination of this lightis not unusual as the power levers are pushed forward past the14,000 RPM position in preparation for take off, but it is notusual for the light to remain on thereafter.) The take off wasabandoned, and the aircraft impounded for further detailed examinationand testing under AAIB supervision. The fault condition was foundto be stable and repeatable, allowing a progressive analysis andtesting program to be undertaken involving all of the relays andsolenoids controlling the propeller lock systems. This identifiedan electrical fault in the flight fine pitch lock removal solenoidon the (replacement) left engine. Replacement of this solenoidby company maintenance personnel effected a positive cure of thefault condition. (It should be noted that the defective solenoidvalve comprised part of the replacement engine, and was not fittedto the aircraft at the time of the original incident.) After satisfactorystatic checks of the propellers, followed by further comprehensivefunctional tests with the engines running, the aircraft was releasedto service with no further faults being reported subsequently.

Fire bottles

Inspection of the engine fire extinguisher bottles showed that,of the four bottles reportedly fired by the crew, only one hadactually discharged. The electrical circuits to the fire bottleswere checked and found to be serviceable. The fuseheads from eachof the unfired bottles were therefore taken to the manufacturerfor inspection and testing under AAIB supervision.

Continuity and resistance checks showed all fuseheads to be withinspecification. One of the fuseheads was fired under test conditions,and was found to perform within specification; the remaining fuseheadswere sectioned and inspected visually, and the charge contentsweighed. Again, no abnormalities were found.

It is possibly relevant that the specification for the fuseheadsallows a firing time of up to 500 ms, ie if the extinguisher*discharge* button is not held down for at least 1/2second, some bottles may not fire.

Flight Recorders

The CVR (Fairchild A100A) and FDR (Sundstrand Universal FlightData Recorder) were replayed satisfactorily using AAIB equipment.The CVR covered a 30 minute period which included the descent,approach and landing into Belfast City Airport. The four trackscontained the pilot's and copilot's microphones, an area microphone,and the public address channel. The FDR recorded five parameters;altitude, airspeed, heading, normal acceleration and flap; therewas no recording of engine power.

The area microphone on the CVR contained frequencies from whichengine RPM could be derived. This analysis showed that when powerwas reduced during the descent, the engine RPM which had initiallybeen around 11,000 reduced to 8,700 RPM. When the landing checkswere carried out the derived engine RPM was 8,200, then flap 26was selected at 149 kt IAS and around a minute later RPM reducedto 7,800. At 130 kts IAS flap 40 was selected with an engine RPMat this stage of 7,500; this RPM gradually reduced during thelanding and ground roll. Higher harmonics of the engine frequencieswere then evident on the recording, and the lowest frequency recordedbefore the signal level became too low gave a derived RPM of 4,000.

A comparison was made with the engine frequencies recorded onanother CVR containing a normal landing on G-JEAH. This showedthat the derived engine RPM was initially around 14,000 RPM. Thisreduced during the approach, and the crew included in the landingchecks a check of the RPM at 11,000 which confirmed the CVR derivedvalue. During final approach the power reduced and after touchdownthe RPM was between 6,830 and 7,500 before power increased againto taxy.

Potential causes of double engine burnout

The CVR recorded verbal comments associated with the movementof the HPC levers from "Lockout" into the "Open"position at the top of descent; however, there is no correspondingconfirmation of them being moved back to "Lockout" priorto the landing approach or subsequently, although a referenceis made during the early stage of the approach to "blue lights".The first indication to the crew that anything was amiss was thefailure to achieve the red 18◦ pitchlights after *ground fine* was selected during the rollout;both amber lights were illuminated, however, confirming the electricaldemand for flight-fine pitch lock withdrawal had been made. Asthe speed decayed through 80 kt both TGTs were seen to be risingthrough 950°C but further attempts by the crew to achieveground fine, including selection of gust locks, failed to producethe desired red lights.

There was no need to advance the power levers to expedite clearanceof the runway or for any other reason, and the crew are positivethat the power levers were not moved at any stage during the landingexcept for their attempts to select ground fine; nevertheless,flames were seen in the exhaust ducts as the aircraft came torest. From the evidence, it is clearly apparent that both propellersmust have hung either on the *flight fine* locks, or the*cruise* locks.

Since both amber lights illuminated after landing, current musthave been supplied successfully to both flight fine withdrawalsolenoids. A failure of either flight fine lock removal solenoidwould have resulted in the *fine pitch lock unsafe* warninglight illuminating on the flight deck; this did not occur. Furthermore,the consequences of both propellers hanging on the flight finelocks is not consistent with the evidence.

Had the propellers hung on the flight fine pitch locks, the RPMsand temperatures during the approach would have been entirelynormal; following touchdown, a failure to achieve ground finewould have resulted in a slow rate of temperature rise, but thiscould not have caused engine damage in the short time betweenthe aircraft touching down and reaching the end of the landingroll. Tests carried out by the AAIB to assess the rate of temperaturerise with the propellers on the flight fine locks confirmed thatthe rate of TGT rise was low, and that it would take at least35 seconds to reach 950°C - even with the aircraft stationarythroughout. For damaging temperatures, ie significantly in excessof 1,050°C, to have occurred during the landing roll, bothpropellers must have been at a pitch setting considerably higherthan flight fine pitch stop, ie hung on the cruise locks.

The CVR analysis showed that the engine RPMs during the subjectapproach were significantly lower than normal. Comparison of thefigures obtained with theoretical RPM-vs-airspeed data suppliedby the propeller manufacturer showed that the RPM decay was comparableto that which would be expected from propellers at the cruiselock pitch setting.

Failure of the cruise locks to withdraw automatically

If, as the crew believe, the HPC levers were placed in the "Lockout"position prior to the start of the approach, and both blue lightsilluminated, then there is no single fault condition which couldhave caused disablement of both cruise lock withdrawal systemsin the circumstances described. Specifically, the action of selectingHPC levers to "Lockout" would have bypassed entirelythe electrical control circuits, and the presence of two bluelights would have confirmed that hydraulic oil at 600 psihad been supplied to the lock withdrawal systems on both propellers.For both propellers to hang on the cruise locks in these circumstanceswould require two entirely separate failures, one on each propeller,involving jamming or partial seizure of the staging valve, thewithdrawal piston or support sleeve, or the lock fingers. Since,neither propeller's mechanical components was disturbed subsequentto the event, and both propellers functioned normally on testand in service subsequently, it is clear that neither propellermechanism can have been defective in the manner implied.

The only defect found, despite extensive investigation, was theexcessive wear of both 34° hub switch brush contacts on theright propeller. With this defect present, it is likely that thehub switch on the right propeller would have been rendered inoperative;intermittently at least. This would have prevented both cruiselocks from withdrawing automatically, but only if the HPC levershad been left in the "Open" position.

History of cruise locks

Service Bulletin F27/61-40

On 9 January 1992, Fokker Aircraft B V issued Service BulletinF27/61-40 applicable to aircraft serial numbers 10102 through10692 equipped with Dart RDa7 engines modified to post SB Da72-198and DA72-348 configuration. This service bulletin comprised proceduralchanges which effectively required the HPC levers to be placedin the "Lockout" position at all times during flight.

In the Bulletin's introduction, Fokker state the following: "Thepurpose of the cruise lock is to prevent inadvertent reductionof propeller blade pitch below the cruise lock position. Sucha malfunction could result in exceeding the maximum RPM for whichthe propeller and engine were designed, and high asymmetric drag.It could be caused by a propeller drive disconnect or a propellercontrol system failure leading to inadvertent movement into finepitch. As operational experience accumulated, the modes of drivedisconnect became known and two improvements to the engine wereintroduced to prevent drive disconnect. Past experience with thelatter standard of engines has demonstrated that drive disconnectis now extremely remote. The effect of high asymmetric drag dueto inadvertent selection of fine pitch without drive disconnecthas proved to be acceptable. Consequently, the cruise lock isno longer necessary."

Compliance with Service Bulletin F27/61-40 was recommended; however,operators generally chose not to implement it.

Hub switch brush wear inspections

The hub switch brushes on G-JEAH were last inspected on 25 April1995, during a C Check, some 584 hours prior to the incident.

In October 1987, Dowty issued a service bulletin applicable toRotol propellers fitted to all Dart engined aircraft, which addressedthe issue of carbon brush wear. In essence, the bulletin specifiedbrush wear tolerances and instructed operators to institute aninterim inspection program during which the brush wear rates inpractice were to be established by each operator, having due regardto variations within the operator's fleet which might cause thebrushes on certain aircraft to wear at higher rates than the norm;for example, on aircraft used for training. Operators were thenrequired to use the information obtained to establish a maintenanceinterval appropriate to their operation, and incorporate suchinspections into their schedules.

At the time the service bulletin was issued, G-JEAH was maintainedunder the auspices of another large F27 fleet operator, and wasinspected in accordance with the findings of that operator's implementationof the service bulletin.

Subsequently, the (present) operator of G-JEAH took over the maintenanceof its own F27 fleet. Since the check interval into which thebrush inspections were incorporated under the new arrangementswas shorter than that applicable previously, it was believed thatthe *new* interval would be acceptable under the terms ofthe Dowty service bulletin. However, no specific account was takenof the increased wear rates which might be achieved on aircraftused for training purposes. In the light of this incident, theoperator is reviewing hub brush wear rates in order to ensurethat the inspection intervals are consistent with the requirementsof the service bulletin.

Flight crew operating instructions

At the time of the accident, the relevant instructions and informationavailable to the crew were contained within the Flying Manualand in "Notices To Aircrew":

Flying Manual:

In the "Descent Checks" the HPC levers could be selected"as required", with the proviso that the TAS was restrictedto 265 kt if the HPC levers were left at "Lockout".

In the "Approach Checks" the HPC levers were to be selectedto "Lockout"; the expanded checklist required a checkthat the two blue lights were on. There was also a note containedwithin the "Flight Handling Section" that the HPC leversshould be at "Lockout" at speeds below 140 kt, to safeguardagainst cruise lock "hang up" causing excessive TGTsat low speed.

In the "Landing Checks" there was no further requirementto check the propeller lights although the commander's normalpractice was to include a check of the blue lights in additionto his checking of gear lights.

Within the "Systems Operations Section" there was thefollowing paragraph: "To safeguard against propeller hangup at the cruise lock, this lock should be manually withdrawnat speeds below 140 IAS (HP cock from OPEN to LOCK OUT). If, after"Lockout" has been selected, the propeller does notpass below the cruise pitch stop (indicated by continued decreasein engine RPM and rise in TGT, even with the cruise pitch stopremoved lights illuminated) the propeller is "HUNG"on the cruise pitch stop."

Notices To Aircrew:

The notice relating to HPC levers was dated 15 March 1993. Itemphasised the need for careful and correct cruise lock controlon the various phases of flight and included the following instructions:

"HP Cocks MUST BE to lockout for take off and climb,there is no requirement to place the HP Cocks to open in the cruise.The temperature at 20,000 ft would have to be in excess of +20°Cto exceed 265 knots TAS.

During descent, the HP Cocks must be moved from lockout to openif the TAS exceeds 265 knots.

Care must be taken when entering the hold or reducing speed aftera high speed descent. If the HP Cocks are left at open (particularlyin the hold) when the speed has reduced to 140 knots or less,and the throttles are opened, the engines can be destroyed inseconds."

After the accident, the following additional Notices To Aircrewwere promulgated by the operator:

The first was dated 11 August 1995 and updated all crews on theprogress of the investigation. It also formalised the requirementto check and call "2 Blues" in addition to the gearcheck during the "Landing Checks".

Thereafter, on 17 August 1995, all crews were instructed to operateHPC levers in "Lockout" and restrict airspeed to below265 kt TAS.

On 14 September 1995, a further notice detailed changes to thechecklists. These were as follows:

Descent Check: "HP Cocks-LOCKED OUT, 265 kt MAX"

Approach Checks: "HP Cocks-LOCKED OUT, 2 BLUE LIGHTS"

Landing Checks: After "Landing Gear" include new check:"Propellers-2 BLUE LIGHTS, RPM 11,000 Approx"

History of propeller induced Dart engine burnouts

Accident reports were reviewed to ascertain the number and extentof engine burnouts on Dart engines in which the propeller cruiselocks were implicated. Between February 1964 and May 1991 a totalof 71 events were identified, of which 25 involved double enginedamage on twin engined aircraft, and 2 involved multiple enginedamage on 4 engined aircraft. The remaining events involved damageto a single engine only. The incident involving G-JEAH is theonly other identified propeller cruise pitch lock related eventsince May 1991.

All except one of these events occurred during flight training(involving low speed handling) or during the approach/landingphase of scheduled operations; the exception occurred shortlyafter take-off when the aircraft entered a heavy rain cloud.

In many cases, detailed information about these events was limited.Nevertheless, of the double engine burnouts, crews apparentlyadmitted to not selecting HPC to 'Lockout' on 5 occasions and,on one fatal accident, the HPC levers were found at 'Open' duringexamination of the wreckage. Additionally, electrical problemswere identified in 10 of the multi-engine occurrences. In theremaining cases of multiple engine burnout, whilst the HPC leverswere reportedly at "Lockout" on all occasions, the availableevidence suggested otherwise.

In those cases involving a single engine burnout, a malfunctionof the cruise lock system on the associated propeller was implicated,rather than a failure by the crew to select 'Lockout'.

During the period reviewed, no report was discovered which involveda propeller drive disconnect or a propeller control system failure,ie the hazardous conditions against which the cruise locks wereintended to protect.

Recommendations

The historical evidence suggests that the cruise locks themselvestend to cause problems, whereas in the case of the F27, the hazardswhich they were designed to overcome do not appear to have materialisedas a significant issue in practice. Since Fokker Aircraft BV statedin Service Bulletin F27/61-40 that "the cruise lock is nolonger necessary", it would appear that the practice of movingthe HPC levers to 'Open' in flight is an unnecessary and potentiallydangerous action. The following Safety Recommendations are thereforemade:

96-9: The CAA should make the implementation of Fokker ServiceBulletin F27/61-40 (requiring high pressure cock levers to bekept in 'lock out' during all phases of flight) mandatory forall F27 aircraft on the UK Register, in order to minimise therisk of turbine 'burnout'. Implicit in this recommendation isthe requirement for all affected engines to meet the modificationstandard specified by SB F27/61-40.

96-10: Fokker Aircraft BV should urge all operators of F27 aircraftto implement Service Bulletin F27/61-40 (requiring high pressurecock levers to be kept in 'lock out' during all phases of flight)in order to minimise the risk of turbine 'burnout'.

96-11: The CAA should review other Rolls Royce Dart powered turbopropaircraft to determine whether engine operating procedures requirechanging to minimise the risk of turbine 'burnout' as a resultof propeller pitch lock malfunction.