Boeing 757-225, G-OOOV, 27 January

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Aircraft Type and Registration:	Boeing 757-225, G-OOOV
No & Type of Engines:	2 Rolls Royce RB211-535-E4
Year of Manufacture:	1985
Date & Time (UTC):	27 January at 0121 hrs
Location:	Birmingham International Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 9 - Passengers - 228
Injuries:	Crew - Nil - Passengers - Nil
Nature of Damage:	Nosewheel axle and two wheel hubs destroyed
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	Not relevant
Commander's Flying Experience:	Not relevant
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was engaged on two sectors; Birminghamto Malaga and return. At the end of the first sector at 1655 hrs,after an uneventful landing at Malaga, the aircraft left the runwayvia the rapid exit taxiway. At a speed of about 20 kt a vibrationwas felt through the steering as the aircraft was turned leftthrough approximately 120°, onto the parallel taxiway. The commanderinitially thought that the vibration was due to the taxiway surface,however, after 100 to 150 yards of straight taxying the vibrationreturned again in a more marked fashion. The aircraft was broughtto a stop immediately and ATC and the airport emergency serviceswere informed. Passengers were disembarked via steps and takenby bus from the taxiway.

Upon inspection the right hand nosewheel wasfound canted over at an angle, the outer bearing having disintegrated.The operator's Duty Engineer, in Maintenance Control at Manchester,was informed at 1715 hrs and despatched an authorised certifyingengineer (a Licenced Aircraft Engineer - referred to throughoutthis Bulletin as 'the LAE'), and a wheel change kit from Manchesterby diverting another Boeing 757, GOOOW bound for Tangier,to Malaga where it landed at 2115 hrs. The LAE visually examinedthe axle and found some axle damage that had been caused by thewheel bearing failure. He dressed out this damage, changed bothnosewheels and OV took off from Malaga on its return flight toBirmingham. The nose gear axle failed inboard of the right handouter bearing land (Figure 1) as the aircraft turned offthe runway at Birmingham.

Subsequent metallurgical examination showedthat the fracture of the axle was the result of the degradationof the axle material properties, due to penetration of liquidcadmium from the surface plating into the steel wall ofthe axle (cadmium embrittlement), while it was subjected to heatingand tensile stresses during break up of the bearing at Malaga.Additionally, the axle had been further weakened by mechanicaldamage to a depth of 33% of the wall thickness, also caused duringthe break up of the bearing at Malaga.

Chapter 055117 of the Aircraft Maintenance Manual(AMM) called up an examination of the nose gear axle for overheatingafter a wheel bearing failure (Appendix 1) and required theuse of a borescope to enable the internal bore of the axle tobe examined for evidence of overheating of the cadmium plating.This check was not known to the Duty Engineer or to the LAEbefore OW departed for Tangier via Malaga, nor was it foundby the Duty Engineer during his subsequent document search. Consequentlythe examination was not carried out. The Duty Engineer continuedto search for repair limits to the axle, but was unsuccessful(because no repairs were authorised).

Detailed Sequence of Engineering events

Actions at Manchester

At 1715 hrs the operator was informed that the aircraft wasunserviceable at Malaga with a right nosewheel bearing collapse.This information was passed to the Duty Engineer, a certifyingengineer with airframe authorisations which included landing gear,who worked as a maintenance co-ordinator in Maintenance Control,located adjacent to the Operations Control. He advised the commanderby telephone that the aircraft could be towed slowly to clearthe taxiway and that the consequential damage to the axle couldbe accepted. By this time the Duty Engineer had anticipated thatan axle change would be required and called the contracted maintenanceorganisation, both at Manchester and Gatwick, to enquire aboutthe availability of two engineers to go to Malaga, but was toldthat they were unable to meet the requirement.

Another aircraft GOOOW, full of passengers and due to takeoff for Tangier at 1800 hrs, was held with the intentionof diverting it to Malaga with wheels and a wheel change kit.At about the same time another certifying engineer ('the LAE')rang Maintenance Control from home to check on shift allocations.He was told by the Duty Engineer that a nosewheel failure hadoccurred in Malaga, that an aircraft full of passengers was waiting,and was asked if he was available. In spite of feeling tired aftera day spent flying a microlight, he confirmed that he was available.At 1730 hrs he was told that his offer to go had been accepted.

The Duty Engineer then spent some time arranging for spare wheels,jacks and tools to be delivered and loaded onto OW. He also provideda photocopy of extracts from the AMM giving torque loading figuresfor the wheel changes. The AMM also contained within Chapter 5- 'Time Limits/Maintenance Checks' a mandatory borescope inspectionto be carried out after a bearing failure to detect cadmium embrittlement,but the availability of this information was not generally knownof amongst the operator's engineers, and the sub-chapter was notconsulted.

At 1815 hrs the LAE arrived at Manchester Airport and askedfor the assistance of a mechanic, who had volunteered to go. However,there was only one spare seat available on the aircraft, and whilstit would have been possible to off load one member of the cabinstaff, the possibility was not considered. OW took off for Malagaat 1825 hrs.

The LAE was therefore sent off without an assistant, without theknowledge that an overheat check was required following a bearingfailure, and without a borescope to enable him to carry out sucha check. He did not have time to look at the AMM at Manchesterand neither OV nor OW carried a copy, so he had no opportunityto see the sub-chapter containing the inspection requirement followinga bearing failure. An AMM could have been obtained at Malaga orpages could have been faxed out by the Duty engineer, albeit perhapswith some difficulty, but the LAE did not see the need to to seeksuch additional information.

The maintenance organisation exposition issued by the operatorand approved by the CAA defined the procedures, acceptedby the CAA, to be used in the repair of aircraft. All certifyingengineers directly employed by the operator would be expectedto know these procedures and would be tested periodically on theircontent. In particular, the exposition required that repairs toaircraft structures which fall outside the scope of the aircraftStructural Repair Manual are to be referred to the Technical ServicesDepartment, who would employ the aircraft manufacturer or an approveddesign organisation to provide an approved repair scheme. Theonly method authorised by the aircraft manuals for the nosewheelaxle was repair by replacement, any other method would thereforerequire an approved repair scheme. The exposition further requiredthat all repairs were to be detailed and documented for recordpurposes.

At about 1830 hrs the Duty Engineer received a call fromOV saying that the aircraft had been jacked, the wheel was off,and the axle was 'not too bad'; but the Spanish engineer was havingtrouble getting the bearing off. At 1900 hrs an avionicsengineer took over as Duty Engineer in the UK maintenance controland passed the information from OV on to the LAE who was by nowairborne in OW. Sometime after 2115 hrs the Duty Engineerwas informed of the extent of the damage to the axle, and he wasstill concerned that no information about possible repair limitscould be found in the aircraft manuals. He therefore contactedthe Boeing 24hour Engineering Support desk to see if thedamage could be worked to limits. Boeing referred the Duty Engineerto the AMM and asked for further details in the form of a sketchif the AMM did not find the information he needed. No furtherinformation was passed because the aircraft was declared serviceableby the LAE in Malaga and it took off at 2259 hrs.

Actions at Malaga

At 2115 hrs the LAE arrived in Malaga and was asked aboutthe anticipated length of the delay as he unloaded kit from GOOOW.He missed the first cue of serious trouble because the damagedwheel was already loaded on OV, and was inaccessible because ithad been placed behind luggage in the forward freight bay. Henoticed that the bush fitted to the inside of the threaded endon the axle was damaged (see Figure 2), as was the axle nut, butdecided not to change the bush as sufficient locking holes remainedavailable. He identified the mechanical damage between the bearinglands on the axle caused by the damaged wheel and bearing, andassessed it as being $1\frac{1}{2}$" long and $\frac{1}{16}$"deep. He could not see any signs of bluing or overheating on theoutside of the axle and considered that it would be satisfactoryfor the aircraft to return to Birmingham, after the damage hadbeen blended. These details were passed to the Duty Engineer inManchester.

The LAE examined the inside bore of the axle after cleaning itas best he could, but as he only had a torch and not a borescopehe could not see 7" into the bore (as the AMM required).He therefore missed the signs of overheating inside the bore ofthe axle as the change of section behind the internal lockingbush hid the damage from a torch inspection. Having decided thatit would be satisfactory to blend the external damage to allowthe return flight to proceed, the LAE did so with a half roundfile and emery cloth. He did not raise an Acceptable DeferredDefect on what he considered to be a temporary repair as he hadno drawings or blend limits to work to. In fact there were nolimits published because no blending was allowed.

During the inspection of the axle he had to handle a distractionfrom the commander of GOOOW, who approached him about arefuelling problem, at that point he gave advice. Later, duringblending, the same commander again approached him with his refuelproblem; this time the LAE left the axle job to assist with therefuelling.

The LAE replaced the right hand wheel, which was fitted withouta problem, and changed the left hand wheel, using the photocopiedmaintenance manual extracts giving the appropriate torque figures.He contacted maintenance control at 2215 hrs, just one hourafter arriving in Malaga, with brief details of the damage andstated that the aircraft was satisfactory for service, but thatan axle change should be planned when the schedule allowed. Itwas agreed that this would happen at Manchester after the Birminghamsector. The aircraft took off for the return flight to Birminghamat 2259 hrs. (Flight crew duty time would have required theaircraft to take off from Malaga by 0200 hrs).

At 0121 hrs OV arrived at Birmingham and landed on Runway33. A replay of the flight data recorder gave the landing parametersfor the last 12 flights. These indicated that the relevant parametersof the accident flight landing, where known, were no worse thanaverage.

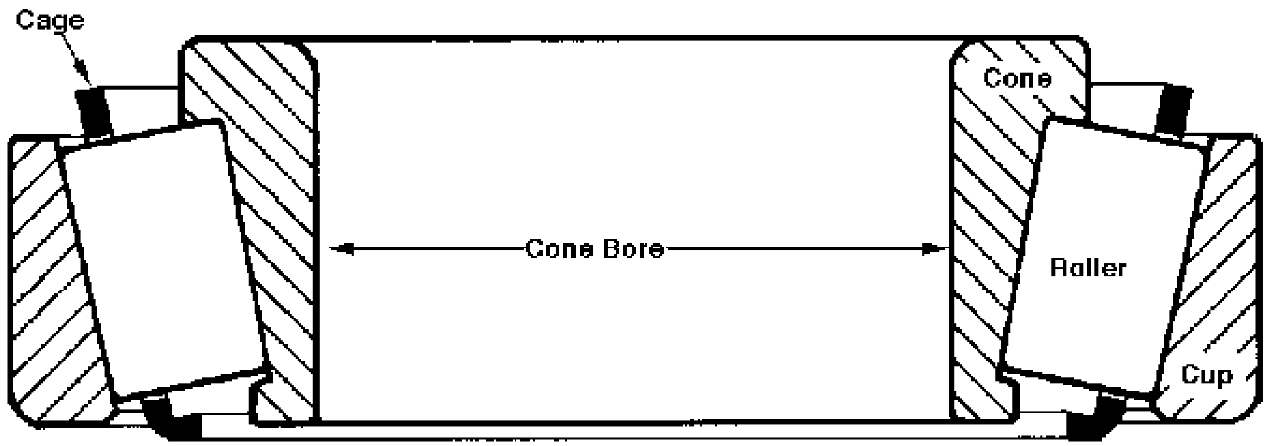
G-OOOV turned off Runway 33 via the rapid exit taxiway; at a speedof 12 kt a 'snap' was heard and vibration was felt throughthe steering. The aircraft was brought to a full stop over a distanceof 20 yards and ATC and the airport emergency services wereinformed. Passengers were disembarked via steps and taken by busfrom the taxiway. Inspection revealed that the nose landing gearaxle had failed inboard of the right hand outer bearing land,in the region of the axle damage dressed out in Malaga.

Subsequent Examination of Components

Bearing Failure at Malaga

The failed bearing had achieved 440 landing cycles sinceinstallation. This life was slightly higher than the average timeto rejection of a random selection of 7 nosewheel bearingsrejected during tyre changes.

The bearing was visually examined by a representative of the manufacturerin the presence of AAIB. With the exception of water corrosionon the cone bore the inboard bearing was in reasonable condition.The outboard bearing was severely distressed with most of thedebris exhibiting plastic deformation from softening at the hightemperatures experienced during the bearing failure.



Fourteen rollers out of a full complement of 27 were availablefor examination. The spherical grinding on the ends of some ofthe rollers was nearly undamaged indicating that wear at thissliding contact area had not been a problem before the rapid collapseof the bearing. The bearing cone also exhibited sections of thrustrib in relatively undamaged condition, again endorsing a rapidcollapse. Several rollers showed line etching caused by watercorrosion, and, in some cases, fatigue damage at these sites ofcorrosion.

It was concluded that the outboard bearing had collapsed rapidly.This is characteristic of a cage failure and may be caused bycorroded and fatigued, spalled roller bodies wearing or 'machining'the cage arms until they are sufficiently weakened to break. Corrosionof bearings on a variety of nosewheel applications is awell known phenomenon as the bearings are generally not backedup with a brake pack which helps shield main wheel bearings fromwater ingress.

Examination of the bearing indicated that there had not been alubricant failure, although the grease may have carried contaminants.The grease recovered from the bearing was therefore examined ina laboratory of the Defence Evaluation and Research Agency (DERA)at Farnborough to check for the presence of water, detergentsor deicers. One grease sample was taken from the wheel carryingthe failed bearing, and another sample was extracted from thebearing components in the laboratory. Unused Aeroshell 5grease, the type used in the bearing, was also examined as a reference.

The water content of the sample taken from the bearing was notsignificantly higher than that of the clean grease. Detergentsand deicers were not found in the samples.

Axle Failure at Birmingham

Visual and macroscopic examination of the axle gave the followinginformation (Figure 3):

a. A generally circumferential fracture had occurred between thewheel bearing lands at one end.

b. There was considerable mechanical damage in the vicinity ofthe separation on the underside of the axle; some of this damagehad been mechanically smoothed out. Measurements showed that upto 33% of the wall thickness had been removed from this region.

c. Some of the chromium plated lands upon which the bearings satvaried in width around the circumference indicating a lack ofconcentricity between the axle centreline and the centreline usedduring the grinding of the lands (although the axle met all ofthe relevant drawing requirements).

Detailed examination of the fracture surface in the initiationregion showed that it had been partially 'wetted' with cadmiumfrom the axle bore. It was also seen that cadmium in the boreat, and adjacent to, the initiation region had melted and re solidifiedas globules. The melting point of cadmium is 321°C.

A section of the initiation region was extracted and polished.It showed that extensive cracking had occurred around the macrograinsas a result of the penetration of liquid cadmium when the materialhad been subjected to tensile stresses. This phenomenon is knownas liquid cadmium embrittlement. Hardness tests indicated thata loss in tensile strength from approximately 118.4 tons/in2to 113 tons/in2 had been causedby the localised heating when the mechanical damage occurred.However, the additional degradation by the liquid cadmium hadfurther dramatically reduced the overall strength. Further hardnesstests showed that a peak temperature of between 400°C and 500°Cwas reached when the axle sustained further mechanical damageat Birmingham (Figure 3).

Axle Dimensions

Some of the chromium plated lands upon which the bearings satvaried in width around the circumference. Measurements taken indicatedthat there was a 0.020" lack of concentricity between theaxle and bearing lands centrelines (see diagram). Whilst this lack of concentricityhad not contributed to the axle failure, it may have indicateda quality discrepancy; the axle was sent to Boeing, who were askedfor their comments.

Boeing received the axle and conducted a thorough dimensionalinspection and analysis, a review of the axle drawing was alsoconducted. The inspection revealed that the axle inner and outerdiameters were concentric to within 0.019" as measured alongits length. The drawing review showed that there was no specificdrawing requirement for the internal diameter (ID) to outsidediameter (OD) concentricity for the design of this axle. The axletherefore met all the applicable drawing requirements as notedon drawing 162N11511, Rev C (dated 10 June 1997).

A review was conducted of other similar axles for which Boeingholds design responsibility. Typically, the drawings called forall IDs (there are several different IDs along the length of theaxle as strength, manufacturing and assembly requirements dictate)to be concentric with a single ID to within 0.010". The lackof such a requirement on drawing 162N1151 appeared to be an oversightduring the design process. This will be corrected with an amendmentissued at the next drawing revision, due for release in the nearfuture.

Several discussions took place between Boeing and the 757 noselanding gear axle manufacturer, Menasco. As Menasco manufacturesother similar axles for Boeing in which the ID and OD concentricityis established, the manufacturing process for these differentaxles is also similar and records are kept for each axle. Unfortunately,the serial number on the failed axle's records was incomplete,and an inspection of the axle did not produce a legible number;therefore the records for this axle could not be traced.

A stress analysis was conducted for the 162N1151 axle, based specificallyon a lack of concentricity between the ID and OD of 0.030".This tolerance, 300% larger than that of other similarly manufacturedaxles, was chosen as an all enveloping tolerance. It was feltthat a lack of concentricity beyond this would make the remainingdownstream manufacturing processes for the axle difficult to completewithout the discrepancy being noticed and the axle rejected. Theanalysis showed a positive margin of safety in both static overloadand fatigue characteristics at this extreme condition.

A search of Boeing's records showed no incidences of 757 noselanding gear fractures as a result of 'thin walls' generated bynon-concentric inner and outer diameters since the original designin 1979. Based upon their assessment, Boeing concluded that thelack of an internal and external diameter concentricity requirementon existing 757 nose landing gear axles does not constitute astructural or functional concern. However, in order to ensurethe consistency and quality of those axles in service, Boeingintend to release a revision to the overhaul manual to inspectthe concentricity of the inner and outer diameters during periodicoverhaul of the axle.

Other Information

The CAA Mandatory Occurrence Reports (MOR)

The CAA MOR data base contained five reports of nose wheel bearingfailures on Boeing 757 aircraft between 1985 and the failure atMalaga described above. The data base contained no previous reportsof nose wheel axle failures.

Duty Engineer's Job Description

The operators exposition contains the following description ofthe Duty Engineer's duties: 'A licenced engineer who operatesas a maintenance coordinator. Effects control of repetitive defects,co-ordinates line engineering activities to ensure that operationalaircraft requirements are satisfied'.

Qualifications and Experience

The LAE who carried out the work on the axle at Malaga was aged36 years and held a current Aircraft Maintenance Engineer's Licencewith company authorisations to issue Certificates of Release toService for repair on nominated systems, including landing gear,on A320200 and Boeing 757200 aircraft. He hadheld the licence since 1982.

On his return to Manchester he was re-examined on company proceduresand his knowledge was found to be satisfactory. He could not accountfor his violation of company procedures at Malaga.

Training

Discussions with several certifying engineers indicated that theywere vaguely aware of the principles of cadmium embrittlement,having heard about the phenomenon during basic training for theirlicences. However, the subject is not generally reinforced laterduring the 757 type rating course. Three training organisationsused by the operator were asked whether cadmium embrittlementwas included in their Boeing757 courses. As a distinct subjectcadmium embrittlement was not discussed on the Boeing757 coursespresented by these companies, although it may be referred to asan aside if there are any ongoing 'in-service' problems relatedto this condition.

Documentation

At the time of the accident the operator was evaluating acomputer based system which would allow personnel at mainbases to access aircraft maintenance documentation from PC workstations.This system was not available on aircraft. Since the accidentthe operator has provided Maintenance Control with two 'fly-awaykits', each comprising a laptop computer with Boeing 757 and AirbusA320 technical information stored on CD ROMs. These kits allowthe user to search the documentation for any word or phrase andwould identify the bearing failure check requirements if a searchwere to be conducted using the word 'bearing'.

Analysis

Bearing Failure

The bearing failure was initiated by water corrosion of some ofthe rollers; this led to heavier roller damage from fatigue. andeventually to break-up of the bearing as the roller cage was broken.The lack of shielding from a brake pack made the Boeing 757nose wheel bearings more susceptible to water ingress than mainwheel bearings. Nevertheless, the CAA MOR data base showed thatfailures of this bearing on Boeing 757s have only occurredin the UK approximately once every two years, and that no axlefailures had been reported.

Axle Dimensions

The failure occurred on an area between the axle bearing landsand the dimensions associated with this area were satisfactory.The dimensions of the bearing lands themselves showed a positivemargin of safety for both the static and fatigue strength of theaxle.

Axle Failure

The axle should have been rejected at Malaga on two counts: thearea between the bearing lands was severely damaged and had suffereda 33% reduction in wall thickness; and the application of theinspection contained in the AMM would have shown symptoms of cadmiumembrittlement. The failure of the axle was therefore a resultof deficiencies in:

The application of basic airframe trade knowledge during the inspectionof the damaged axle,

The knowledge of the check for cadmium embrittlement requiredby the AMM,

The provision of information for the use of the LAE,

The Quality oversight of the operations in Malaga.

Training

The LAE held a basic licence and was trained to hold anauthorisation for the relevant systems on the Boeing 757,he was experienced on type and was familiar with the operator'sprocedures to be used during rectification. He was not aware ofthe requirements of the AMM chapter dealing with landing gearwheel bearing failures and did not recognise that the axle wassusceptible to cadmium embrittlement.

The subject of cadmium embrittlement, and its relevance to Boeing 757landing gear axles, was not covered on three 757 type rating coursesexamined by the operator. It is recommended that organisationsoffering type rating courses amend their syllabus to include thesubject of cadmium embrittlement, where relevant.

The Despatch of G-OOOW

The decision to divert GOOOW to Malaga reduced the preparationtime available to the Duty Engineer, and this had far reachingconsequences. Although he realised that the incident (as it thenwas) was probably going to result in an axle change because ofboth the mechanical damage caused by the failed bearing and thesubsequent damage incurred during the towing of OV off the taxiway,he spent 40 minutes arranging a wheel change kit. No provisionwas made for an axle change, nor for documentation or borescopeequipment to help assess the damage to the axle.

The use of OW and the implicit timescale imposed precluded aneffective assessment of the probable technical problems, and theprovision of appropriate information and equipment. A satisfactorysolution could only have come about if the engineering problemswere considered separately from the logistic problem. It is recommendedthat the operator carefully defines his logistic and engineeringpriorities in a situation where rectification is required downroute.

Documentation

The LAE was despatched without knowledge of the contents of theinspection required by the AMM following the wheel bearing failure,and without knowing that such an inspection existed. He had nochance to correct this situation during his free time on the flightto Malaga because neither he nor OW carried maintenance manuals.Thus he remained ignorant of one of the two rejection criteriafor the damaged axle.

The use of the fly-away kits containing a laptop computer andaircraft documentation now provisioned by the operator would haveenabled the LAE to find the appropriate references. However, unlesssuch a search was carried out at a main base before despatch,the provision of the borescope equipment would still present alogistic problem. It would therefore be prudent to provide MaintenanceControl with a similar facility.

Actions in Maintenance Control after the despatch of OW

Before OW took off no-one in Maintenance Control had consideredthe possibility of an attempted temporary repair (rather thanby replacement) to the axle, and no-one therefore considered theneed to involve Quality Assurance or Technical Services Departmentpersonnel for guidance. The situation was exacerbated by the optimisticassessment of the axle condition received in Maintenance Controlat 1830 hrs from OV. It was not until after 2115 hrsthat the replacement Duty Engineer received a detailed assessmentof the axle damage from the LAE. This was only some 90 minutesbefore OV took off for Birmingham.

Once the extent of the damage became known to the Duty Engineerhe attempted to find repair limits in the AMM, but was unsuccessful.He then contacted Boeing in the hope that they could refer himto some existing limits. During this period Quality Assuranceor Technical Services Department cover from the operator's resourcescould have been provided by personnel available on-call at home.However, the overall time scales tacitly accepted by the decisionto use OW, and the speed of events in Malaga, mitigated againstthe recall and use of these personnel.

Although the Duty Engineer was responsible for co-ordinating themaintenance engineering activities concerning OV, he was the samegrade as the LAE sent to Malaga, an LAE employed in therole of Duty Engineer himself. After 1900 hrs that nightthe Duty Engineer was an *avionics* tradesman, and he mayhave been reluctant to express any concern that he may have feltabout the lack of repair limits to a *airframe* tradesman,'on site', of the same grade and dealing with a component thatfell within his specialisation.

Work at Malaga - Procedures and Quality

The LAE was unaware of the cadmium embrittlement rejection criteriaand did not have access to the borescope equipment to allow himto apply them, he was therefore left with the physical damageplainly visible on the outside of the axle.

In spite of knowing that he was operating outside the scope ofthe company procedures, the LAE felt it necessary to carry outunauthorised work on the axle. This decision was illogical andagainst all his training; and subsequently the LAE offered noevidence to mitigate the seriousness of his violation of proceduresand professional standards. Nevertheless it is possible that othercertifying engineers, faced with the same circumstances, wouldhave taken similar decisions.

The dressing-out of the abrasion damage would have had a negligibleeffect on the remaining static strength of the axle, and wouldonly have affected the long term fatigue strength; it was thereforenot relevant to the problem in hand. It is obvious that this action,and the fitting of two new wheels to the badly damaged axle, constituteda major breach of quality, which the quality system was too fragileto prevent.

The type of certifying engineer employed by airlines tocarry out defect rectification at route stations is usually intelligent,experienced and resourceful. He has appropriate company authorisationswhich give him the power to declare an aircraft serviceable *orunserviceable*. He is stimulated by the challenge and stressassociated with his job. He knows that if he fails to return theaircraft to service the passengers will be highly inconvenienced,and the company will be faced with a considerable cost to provideadditional accommodation and/or transport. Such a person is resoluteand confident and is sometimes embued with a high amount of 'CanDo' spirit, which for the most part, works in the operator's favour.In this case the LAE returned to Birmingham with the passengers,and would no doubt, have accepted the approval expressed by themduring the flight. Equally, had he not declared the aircraft serviceable'he' would have 'failed' and felt the passengers' displeasure.There may also have been the unexpressed, but perceived, impressionthat he had let down his colleagues and his company. However,the engineer is trained, examined and granted an authorisationbased on the premise that he is not at liberty to deviate fromthe company procedures or airworthiness data, without specificauthority.

The LAE, who was probably tired as a result of his daytime activities,had asked for a mechanic, but one was not provided because ofnon-engineering reasons. He therefore had no-one to act as a backstopor to question his actions. The procedures governing his actionsshould have been more robust and should have removed the perceptionthat if the aircraft was not recovered it was 'his' fault. Achievingquality in the repair to be undertaken was totally dependant onthe judgement and actions of the one individual, operating inisolation, without the requisite information or significant localresources and acutely aware of the implications of not succeedingin returning the aircraft to service. The success or failure ofthe Operator's quality system was dependant on the performanceof this one individual and was, in these circumstances, shownto be fragile.

The quality system should not allow individuals to be put intosuch a position. The operator's Maintenance Control, acting independentlyand outside the highly charged environment of the aircraft, couldvet and ratify any repair decisions taken away from a main base,whether they are explicitly covered by the aircraft manuals ornot. If the aircraft remains unserviceable it is then because'engineering' have grounded it, and a significant proportion ofthe pressure on the certifying engineer would be removed.

It is recommended that the CAA requires the operator to reviewtheir procedures for maintenance away from a main base with theobject of making them more robust, ensuring compliance with theAMM and removing some of the pressure from the certifying engineerssent to rectify aircraft down route.

Recommendations

Recommendation 98-31

It is recommended that the CAA require organisations offeringtype rating courses to amend their syllabus to include the subjectof cadmium embrittlement, where relevant.

Recommendation 98-32

It is recommended that the CAA requires the operator to reviewtheir procedures for maintenance away from a main base with theobject of making them more robust, ensuring compliance with theAMM and removing some of the pressure from the certifying engineerssent to rectify aircraft down route.

Recommendation 98-33

It is recommended that the operator carefully defines his logisticand engineering priorities in a situation where rectificationis required down route.

Subsequent Action

The operator has reviewed procedures and implemented the necessarychanges. The Quality Assurance Department now examine the contentof all type training courses and from May 1998 they will operatetheir own line stations in the UK, with sufficient staff to facilitatedown-route rescues.

Appendix 1 Wheel Bearing Failure/Damage Condition -Maintenance Practices Conditional Inspection

(8) Do an inspection of the Nose GearAxle.

(a) Visually examine the wheel bearingwasher, axle nut, and inner wheel bearing spacer for scoring orother damage.

1) Replace or repair the componentswhen it is necessary.

(b) Examine the axle for damage.

1) Examine for scoring or discolorationof the chrome plated bearing lands on the axle.

2) Examine the light grey hydraulicfluid resistant paint on the axle for a brown shade caused whenit becomes too hot.

3) Examine the green primer on the innersurfaces (bore) of the axle with a borescope.

a) Use the borescope to a minimum depthof 7 inches and look for discolouration or blistering.

b) The green primer will turn to a lightbrown or black colour when it becomes too hot.

NOTEIf the paint shows only a small discoloration, you can do theheat damage inspection when the airplane goes back to the primarybase. Do not make a landing more than three times before you dothis inspection.

(9) If signs of heat damage are foundin the above steps, do the Heat Damage Inspection.

(10) Replace or repair the damaged componentsas follows:

(a) If the cadmium plate on the axlebore shows signs of heat damage.

NOTEHeat damage to the cadmium plate can cause cadmium embrittlementof the steel substrate.

(b) If the chrome plate on the outerpart of the axle shows signs of heat damage.