ACCIDENT

Aircraft Type and Registration:	Bombardier CL600-2B19 CRJ200, D-ACHA
No & Type of Engines:	2 General Electric CF34-3B1 turbofan engines
Year of Manufacture:	2000
Date & Time (UTC):	13 November 2008 at 0900 hrs
Location:	Manchester Airport
Type of Flight:	No flight planned
Persons on Board:	Crew - None Passengers - None
Injuries:	Crew - N/A Passengers - N/A Others - 1 (Serious)
Nature of Damage:	Nose landing gear damaged
Commander's Licence:	N/A
Commander's Age:	N/A
Commander's Flying Experience:	N/A
Information Source:	AAIB Field Investigation

This occurrence did not meet the description of an accident or serious incident, as detailed in The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996. However, considering the air safety lessons which could be drawn from it, the Chief Inspector ordered an investigation under Regulation 8(4) of those Regulations.

Synopsis

Whilst a technician was rectifying an under-inflated tyre, a pressure of approximately six times the normal tyre pressure was developed. The tie bolts on the wheel failed, the assembly exploded and the technician was seriously injured.

Two Safety Recommendations are made.

Background

During the pre-departure inspection on the aircraft, before an evening flight, one of the flight crew noted a small cut in a main-wheel tyre tread. He reported his findings to his company's main engineering control centre in Cologne. They determined that the damage was beyond acceptable limits and advised the crew. The flight was cancelled and preparations were made to rectify the defect.

A technician from one of the operator's bases in Germany was tasked with carrying out a wheel change and also directed to carry out the five-day maintenance check which was shortly due on the aircraft. He travelled to Manchester the following morning, taking with him a wheel-change kit and a spare main-wheel with a tyre already fitted. The latter was inflated to

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the standard low figure of approximately 50 psi, as released from the company tyre bay.

Following his arrival, the technician was met by staff of a local line maintenance company and was taken, with the spare wheel/tyre and the wheel change kit, to the remote stand to which the aircraft had been towed. A nitrogen pressure rig, the property of the company, was also taken to the aircraft in anticipation of the requirement to inflate the replacement tyre fully once it was fitted to the aircraft.

As the technician worked on the aircraft, another company employee occupied its cabin, performing unrelated tasks.

The maintenance task

The technician elected to carry out the five-day maintenance check before the wheel change. This included a check of all tyre pressures, using a gauge carried within the wheel-change kit. He determined that the right nosewheel tyre was slightly under-inflated and utilised the nitrogen pressure rig to replenish it. The technician was unfamiliar with the rig and had difficulty operating it. He subsequently informed the BFU (German Federal Bureau of Accident Investigation) that he initially opened the valve of one of the bottles using the special spanner provided. He did not check the pressure gauges on the regulator valve, nor did he adjust the valve. Before making the connection to the tyre he confirmed that gas was flowing from the inflator when its lever was activated.

He stated that he then screwed the adaptor into the nosewheel tyre valve. He briefly pressed the inflator lever twice and had the impression no nitrogen entered the tyre. He unscrewed the adaptor and checked the tyre pressure again using the gauge brought with the wheel-change kit. He found that the tyre pressure had decreased by 5 psi. He then re-connected the adapter to the tyre valve. He pressed the inflator lever once or twice again and the wheel burst.

Wheel fragments were scattered across the apron and serious injuries were inflicted on the technician. On hearing the explosion and feeling the aircraft move, the other company employee exited the cabin and noted the sound of escaping gas as he went to the assistance of the injured technician.

Design of wheel and pressure rig

Wheel

The wheel was one of a pair mounted on a common axle on the nose leg of the aircraft. It consisted of two forged halves joined by eight tie bolts. It was small in diameter (approximately 29 cm) and the tyre cross-section was also small (approximately 10 cm x 10 cm). The normal inflation pressure was 163 psi. (Tyre pressures, as well as all system pressures, are quoted in psi in the CRJ 200 manufacturer's maintenance manuals and other technical documentation.)

Provision for an over-inflation pressure relief valve was present in the wheel design. Incorporation of this feature was an operator option but it was not fitted to either of the nosewheels on this aircraft. The wheel manufacturer stated that, during development, an uninstalled wheel/tyre combination was subjected to an over-inflation test. Following steady inflation with two three-second pauses, the wheel failed at 997 psi pressure as a result of tensile rupture of all eight tie bolts.

Pressure Rig

The origin of the pressure rig could not be established; no external type identification was present and the

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owning company were not able to state when or by whom it was built. It did not appear to be a standard proprietary design in that nobody was able to identify any other identical rigs at Manchester or elsewhere.

The unit consisted of a light trailer carrying two horizontally orientated nitrogen cylinders and a locker containing pneumatic components. Each cylinder incorporated a standard, spanner-operated shut-off valve and had a rated pressure of 230 bars (3,335 psi).

The rig had only one adjustable regulator controlling both cylinders. A flexible hose from each cylinder was connected to a manifold, from which a single pipe was routed to the regulator positioned directly above. Both the manifold and the regulator were housed in the locker. The regulator incorporated two gauges, one measuring the pressure supplied from the gas bottles, the other measuring the delivery pressure to a long flexible hose supplying the inflator. The regulator was of a widely used type and did not incorporate any annotations by which the position of the control knob could be referenced; pressure setting relied on rotating the knob until the observed delivery pressure on the appropriate gauge reached the desired figure. The regulator was configured to be capable of delivering gas at pressures of up to 1,500 psi.

The inflator, incorporating a valve operated by a trigger lever, supplied a shorter flexible delivery hose. The hose was connected to the inflator via a bayonet fitting, with a tyre valve connector at its opposite end. A pressure gauge was mounted on the inflator unit, metering the pressure downstream of the lever operated valve. Two delivery hoses were available, with alternative end fittings, enabling different sizes of tyre valves to be serviced.

The pressure gauge, metering the supply from the gas bottle(s) in use and mounted on the regulator valve, was calibrated from 0 to 4,500 psi, with a co-incident scale in bar. The other gauge on the regulator valve, metering the delivery pressure to the inflator, was only annotated in the range 0 to 400 bar. The gauge on the inflator was calibrated in the range from 0 to 350 psi.

The design of the inflator incorporated internal galleries of small cross-section to limit the rate of rise in tyre pressure. The manufacturer stated that it was intended to be used with an in-line regulator. It was labelled accordingly but no regulator characteristics were specified. The inflator manufacturer also stated that their units were supplied to both builders of rigs and as stand-alone inflators to airlines and aircraft maintenance companies. The manufacturer, a supplier of tyre inflation equipment to the aviation industry, indicated that the gauge on the inflator would suffer permanent deformation of the pressure capsule at applied pressures above 500 psi.

Although an annual overhaul of the inflator was recommended by the manufacturer, their records showed that this inflator had not been returned to them since build. The inflator was supplied to the line maintenance company on 13 April 2005.

No operating instructions or warnings were visible on the rig. The only annotation was the name of the owning company.

Examination of aircraft wheel and pressure rig damage

The right hand nosewheel of the aircraft had failed in such a way that the outboard wheel-half had been ejected, with a section of its rim separating either during wheel failure or at subsequent impact. The inner wheel-half

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had shattered into a large number of fragments. These were scattered widely around the apron. The central nut securing the wheel to the axle had separated in a manner consistent with being driven axially along the thread by a substantial force. Seven of the eight tie bolts had failed and their parts were distributed about the apron. Subsequent metallurgical analysis revealed that each bolt had suffered staged tensile rupture near the run-out of the thread forms. The tyre was lying nearby having sustained no significant damage.

Overload failure of all but one of the tie bolts was the initial mechanism of the failure. No pre-existing defect was identified in the wheel, tyre or bolts. The characteristics of the failures were consistent with a series of increasing tensile loads which eventually exceeded the yield point of the bolt material.

The rig was examined some hours after the accident and it was noted that the supply pressure gauge to the regulator from the manifold was registering 500 psi; conversation with a flight-crew member from the operator, who made his way to the aircraft following the accident, revealed that it had been noted as reading 700 psi shortly after his arrival. The delivery gauge pressure from the regulator valve was reading zero. The gauge on the inflator was registering 30 psi and remained at that figure.

During the initial examination, the gas continued to escape audibly from some part of the system. One of the rig owner's technicians, familiar with the rig, was asked to make it safe. It was observed that he screwed the regulator valve fully shut and used the spanner provided to shut off the gas bottle.

The delivery hose, incorporating the smaller of two tyre valve connectors which had been in use at the time of the accident, was severely damaged in the event. The fitting of the bayonet connection between the output end of the inflator and the delivery hose had fractured, leaving one end of the inflator still lodged within the body of the hose end fitting. The remains of the tyre valve were identified within the other end fitting. The delivery hose had failed at both swaged joints to the end fittings, ie at the inflator end and at the tyre valve end. The supply hose to the inflator, from the regulator valve, was not damaged.

Further examination and testing

An examination of the inflator and its connections to the supply and delivery hoses was carried out by the inflator manufacturer, in the presence of the AAIB. It was noted that a number of components were not of the type manufactured or utilised by the inflator manufacturer and that the last assembly of the unit had used sealants which differed from those invariably used by them for manufacture or during overhaul of units returned to them. Also, the felt type air filter was excessively contaminated suggesting that it had been subjected to prolonged use without replacement.

Examination of a newly assembled inflator was carried out, followed by a functional demonstration. This showed that once the delivery hose was connected to the valve of an inflated tyre, the pressure of that tyre registered on the gauge mounted on the inflator. Once the lever on the inflator was slightly depressed, the pressure in the tyre was lowered as a result of a small flow of nitrogen venting from the body of the inflator. The decreasing tyre pressure continued to register if the lever remained slightly depressed and also registered if the lever was released.

With the lever further depressed, pressure was supplied to the tyre. Whilst this pressure was delivered, porting within the inflator isolated the gauge, preventing it from

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registering any pressure figure. On release of the lever the newly increased pressure registered on the gauge.

The damaged inflator was then dismantled and its parts examined. It was noted that a secondary seal was severely worn and one of two ring seals was absent from the main spool valve.

The inflator was re-assembled using its same internal components but with a new pressure gauge and replacements for the fractured and damaged external components. The re-assembled unit was then connected to a supply hose, with an appropriate regulator, and to a delivery hose. It was functionally tested.

Once the delivery hose was attached to the valve of an inflated tyre, it was noted that the tyre began to deflate immediately in the same way as it had done when the lever on a correctly functioning inflator was slightly depressed, ie with nitrogen escaping from the inflator unit. During this process the gauge continued to register the decreasing tyre pressure. With full depression of the lever, the tyre inflated in the normal way and the inflator mounted gauge did not register.

Subsequent testing of the regulator unit in the manufacturer's high pressure facility confirmed that the gauges mounted on it remained accurate. Adjustment of the control knob enabled the delivery pressure to be reduced progressively to lower figures until complete shut-off was reached. No delivery pressure creep was observed when the valve was left for a period at mid settings with a high pressure supply connected.

Technical personnel

The technician who was injured had been employed as an aircraft maintenance engineer with the operator, in his native Germany, for 16 years. He had accrued 10 years experience as a LCT (Large Civil Transport) aircraft mechanic holding the highest qualification, Cat B1 Licence, on four types of aircraft. He was fully familiar with the task of inflating aircraft tyres and familiar with the use of pressure rigs. However, he subsequently stated that he had not previously encountered the type of pressure rig in use on this occasion.

General

The local line maintenance company had no approvals or qualified personnel enabling them to provide technical support on the aircraft type, other than supplying general purpose tools and equipment. This was their role at the time of the accident. Documentation supplied by them indicated that the two gauges on the regulator, as well as that on the inflator, had all been calibrated by a qualified company during the previous 12 months. The gauges were annotated accordingly. No records were kept of the usage pattern of the rig. Therefore, the setting of the regulator at the time the work on D-ACHA's nosewheel began was unknown.

The manufacturer of the inflator stated that its records indicated that the component had been supplied to the third party maintenance company three years before the accident. They had no record of it being returned to them for overhaul/repair in the intervening period. They did not publish overhaul manuals for their inflator for distribution outside their own organisation, nor did they supply spares to enable overhaul to be undertaken by other organisations. Thus, without returning inflators to the manufacturer on an annual basis, their recommendations could not be carried out.

Those which were periodically returned for overhaul were frequently noted as being in the possession of organisations other than the original customers. Airline bankruptcies and company take-overs complicated

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the task of tracing the whereabouts of inflators once they had been delivered to airlines and maintenance companies as stand-alone items. It was not, therefore, feasible for the inflator manufacturer to successfully notify operators when the overhaul dates became due.

Examination of other pressure rigs

Mobile pressure rigs are categorised as tools and are not subject to regulation of design, maintenance and operation by the airworthiness authorities, in the same way as aircraft. All such equipment and working practices in the UK are subject to regulation by the Heath and Safety Executive (HSE). They advised that the Health and Safety at Work Act 1974 and the Provision and Use of Work Equipment Regulations 1998 (PUWER) encompass the use of this type of equipment. These regulations only apply in the UK.

Use of high pressure air supplies involves potential risk and it is important that pressures higher than the maximum design pressure are not supplied to pressure vessels, including tyres. Civil aircraft tyres rarely operate at pressures exceeding 300 psi, whereas certain other pressure vessels on aircraft, such as hydraulic accumulators and landing-gear struts, can have rated pressures of many times this figure. Numerous types of pressure supply equipment are used on airport aprons and in maintenance facilities worldwide. Some items are dedicated to special purposes, with appropriate pressure capabilities, whilst others are general purpose rigs designed to supply any pressure up to the maximum needed by the components with the highest pressure ratings in any aircraft. In general, rigs of a type used for both tyre inflation and inflation of higher pressure components have separate controls and individual regulators for each pressure range. They are usually appropriately annotated and often colour coded to prevent inadvertent connection of the higher pressures to tyres and other vessels requiring only low pressures.

Some aircraft manufacturers supply man-portable, dedicated tyre inflation rigs. These have maximum pressure capabilities, limited to figures only slightly in excess of rated tyre pressures and below the maximum that tyres and wheels on their aircraft types are capable of sustaining.

Wheel and tyre design considerations

Federal Aviation Regulations (FAR) Part 25 – '*Airworthiness Standards: Transport Category Airplanes'*, Section 731 - *'Wheels'* recognises the hazard caused by excessive pressure in aircraft tyres and stipulates the requirement for overpressure burst prevention. The regulation states:

> *'Means must be provided for in each wheel to prevent wheel failure and tire burst that may result from excessive pressurization of the wheel and tire assembly.'*

An identical regulation is contained in the EASA's document CS 25 – *Certification Specifications for Large Aeroplanes*, Subpart D – *Design and Construction*, paragraph CS25.731 - *Wheels*.

These are requirements which apply to the certification of new designs but were not in force at the time the CRJ 200 was certificated.

Additional information

This type of occurrence does not meet the internationally agreed definition of an aircraft accident and it has not been possible to determine the rate at which such events occur. However, one manufacturer of large aircraft, on becoming aware of two related events, circulated

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a message to operators advising them of two fatalities, one occurring in 1998 and another in 2006, which took place during tyre inflation operations. Reference was made to safety training information that was available.

Safety action

The HSE undertook to establish actions that the line maintenance company, which owned the nitrogen pressure rig, should take in relation to the design of the rig and the procedures for its use, to prevent a recurrence of this accident. This included a means of separating the higher pressure (0-1,500 psi) and lower pressure (0-400 psi) functions, and the need for the delivery pressure gauge to be marked in units of psi. The HSE also stated its intention to bring the accident to the attention of the HSE sector that advises HSE Inspectors who deal with airports, to capture the high pressure gas rigs that exist at other maintenance firms in the UK.

Discussion

It has been deduced from the extent and nature of the wheel damage and the method of separation of the securing nut from the axle, together with the metallurgical features of the failed tie bolts, that the accident occurred when the internal tyre pressure reached too high a figure. The characteristics of the failures were consistent with a series of increasing tensile loads which eventually exceeded the yield point of the bolt material. This was probably the consequence of briefly releasing and then re-applying hand pressure to the inflator operating trigger lever as the tyre pressure approached the figure required to fail the tie bolts.

Manufacturer's tests had previously demonstrated that wheel failure by a similar mechanism to that occurring in this accident takes place at a tyre pressure of approximately 1,000 psi (approximately six times the normal tyre pressure). Similarly, the permanently elevated position of the inflator gauge indication following the accident confirmed that pressure in excess of 500 psi had been applied at some stage. The fact that the wheel/tyre combination was carrying a proportion of aircraft weight and the wheel was secured to the axle by the nut at its centre, probably accounted for the slight difference in failure mechanism from that reported during the wheel manufacturer's qualification test.

It follows that the regulator on the rig was set to deliver a pressure of the order of 1,000 psi or above, permitting the cylinder in use to supply such a high gas pressure to the inflator. The technician reported that he did not alter the regulator setting and, since the usage pattern of the rig is not recorded, it was not possible to establish when the regulator was last adjusted or to what maximum delivery pressure figure it was set.

Although the inflator was designed, by means of passages of small cross-section, to limit the flow rate of nitrogen to the tyre, this did not prevent over-inflation on this occasion. Inflation of large tyres using this type of inflator would normally result in a relatively slowly rising tyre pressure and a correspondingly slow increase in indicated pressure on the inflator mounted gauge on each occasion the lever was released. By contrast, the low volume of the nosewheel tyre on this aircraft type would have resulted in a much more rapid rise in pressure as the trigger lever on the inflator was depressed.

The restriction created by the limited internal dimensions of the inflator appears not to have slowed the flow rate sufficiently on this occasion for the technician to become aware of the pressure rise and release the lever in time. The absence of the O-ring seal on the main

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spool valve, within the inflator, resulted in the tyre deflating when the lever was released, as well as when it was lightly depressed. With partial depression of the lever, the tyre would have continued to deflate, rather than inflate. The technician might not have expected this. It is probable that on the second occasion of the two short pressure applications that the lever was depressed further. This would have permitted full supply pressure to be delivered to the tyre.

Without the regulator being set to reduce the cylinder pressure to a figure near the rated pressure of the tyre, a moderately lengthy period spent with the lever fully deflected would have enabled the pressure in the small tyre to rise far above its rated value. A process by which the grossly elevated tyre pressure failed the wheel tie bolts can thus be envisaged.

It is not unusual for aircraft maintenance companies to use high pressure nitrogen supplies for a variety of purposes as well as for tyre inflation. It is usual to use clear annotations to ensure that only appropriately regulated pressures are delivered to tyre valves and the higher pressure supplies are restricted to use for accumulators, oleo struts etc.

The original purpose of the rig used on this occasion could not be determined, but personnel from the owning company have stated that it was only used for inflating tyres. It bore no annotation, however, drawing the attention of operators to the fact that it was capable of delivering pressures far in excess of that required for tyre inflation. Also, the delivery pressure indication on the rig was in bars while all other annotated pressures (as well as most quoted aircraft tyre pressures) were in psi.

The movement of the needle on the delivery pressure gauge on the regulator valve, required for normal tyre inflation, was a small proportion of full scale deflection. A technician unfamiliar with the rig may not have appreciated that a setting of the regulator which gave an output pressure reading on the gauge well below the full-scale value was nonetheless capable of transmitting a pressure many times in excess of that which was required. The use of a scale in bars, where the full-scale reading of 400 was in the region of twice the numeric value associated with tyre pressure range on typical airliners (invariably in the range 150 to 250 psi), may also cause an operator to assume it is calibrated in the widely used and familiar psi units. Operators may not notice the very small annotation of the word ‘bars’ on the face of the gauge. Therefore, the technician could have left the regulator to supply nearly 15 times the pressure he assumed was available.

Although the first observation of the supply pressure, noted some time after the accident, was 700 psi, the occupant of the aircraft cabin recalled the sound of escaping gas immediately he exited the aircraft, following the explosion. It can be surmised that considerable gas escaped between the accident and the first occasion that the gauge reading was noted. The pressure available from the cylinder in use at the time of the wheel failure is, therefore, not known but may have been in excess of the 700 psi figure observed by the company pilot and possibly up to the region of the 3,335 psi of a newly replenished cylinder. The regulator would have restricted the pressure supplied to the wheel to a maximum of 1,500 psi.

The requirement for overpressure burst protection exists for wheels and tyres on new aircraft complying with FAR Part 25 and the EASA’s CS 25. In view of the lack of consistent regulation covering pressure rigs to be found on airfield aprons worldwide, any attempt to control the risk of wheel/tyre explosions during tyre

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inflation would have to centre on wheel/tyre design. Consequently, extension of the FAR Part 25 and CS 25 requirements to all aircraft which fall into this category, but were certificated prior to the requirement, should be considered. Had overpressure burst protection been fitted to this aircraft, it is probable that the accident would not have occurred. This is not the first occasion on which such bursts have happened and previous such events have resulted in fatalities.

The following Safety Recommendations are made:

Safety Recommendation 2010-069

It is recommended that the Federal Aviation Administration review the number of occurrences of the overpressure failure of tyres or wheels on Transport Category Airplanes and consider retrospectively applying the requirements of Federal Aviation Regulations Part 25.731, for Overpressure Burst Protection on the wheels of Transport Category Airplanes.

Safety Recommendation 2010-070

It is recommended that the European Aviation Safety Agency review the number of occurrences of the overpressure failure of tyres or wheels on Large Aeroplanes and consider retrospectively applying the requirements of CS 25.731, the Certification Specifications for Large Aeroplanes for Overpressure Burst Protection on wheels.

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