Inquiry AO-2013-007: Boeing 737-838, ZK-ZQG,
stabiliser trim mechanism damage, 7 June 2013

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Final Report

Aviation inquiry 13-007

Boeing 737-838, ZK-ZQG
stabiliser trim mechanism damage

7 June 2013

Approved for publication: February 2015

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is a standing Commission of inquiry and an independent Crown entity responsible for inquiring into maritime, aviation and rail accidents and incidents for New Zealand, and co-ordinating and co-operating with other accident investigation organisations overseas. The principal purpose of its inquiries is to determine the circumstances and causes of the occurrences with a view to avoiding similar occurrences in the future. Its purpose is not to ascribe blame to any person or agency or to pursue (or to assist an agency to pursue) criminal, civil or regulatory action against a person or agency. The Commission carries out its purpose by informing members of the transport sector and the public, both domestically and internationally, of the lessons that can be learnt from transport accidents and incidents.

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Important notes

Nature of the final report

This final report has not been prepared for the purpose of supporting any criminal, civil or regulatory action against any person or agency. The Transport Accident Investigation Commission Act 1990 makes this final report inadmissible as evidence in any proceedings with the exception of a Coroner's inquest.

Ownership of report

Citations and referencing

Information derived from interviews during the Commission's inquiry into the occurrence is not cited in this final report. Documents that would normally be accessible to industry participants only and not discoverable under the Official Information Act 1980 have been referenced as footnotes only. Other documents referred to during the Commission's inquiry that are publicly available are cited.

Photographs, diagrams, pictures

Unless otherwise specified, photographs, diagrams and pictures included in this final report are provided by, and owned by, the Commission.

Boeing 737-838 (registration ZK-ZQG)
Courtesy of Jetconnect Limited

Source: mapsof.net

Location of incident

Contents

Figures

Abbreviations

ATSB	Australian Transport Safety Bureau
CAA	Civil Aviation Authority of New Zealand
Commission	Transport Accident Investigation Commission
NTSB	National Transportation Safety Board
NZWTA	New Zealand Wool Testing Authority
UTC	Coordinated Universal Time

Glossary

B737-838	a Boeing 737-800-model aircraft that was ordered by Qantas Airways Limited. The number 38 added at the end of the model number is the customer code for Qantas and stays with the aircraft for its entire service life
cable drum	part of a closed-loop-control cable system that transmits the rotation movement of a drum through cable windings and along a cable run to another part of the control system, where it is converted into a linear or rotational output
horizontal stabiliser	a fixed or movable aerodynamic surface on which pitch-control surfaces (elevators) are mounted. It provides stability in pitch, and can also be moveable for the purpose of trimming
jackscrew	a type of jack that converts the rotational input of a screw into a linear movement output (similar to a motor vehicle jack)
stabiliser trim	a flight control system that changes the angle of the horizontal stabiliser, which adjusts the amount of downwards or upwards aerodynamic force produced at the tail of an aircraft in flight. It is used to compensate for changes in centre of gravity and to maintain a wide range of airspeeds

Data summary

Aircraft particulars

Aircraft registration:	ZK-ZQG
Type and serial number:	Boeing 737-838, 34190
Number and type of engines:	two CFM56-7 turbofans
Year of manufacture:	2011
Operator:	Jetconnect Limited

Date and time 7 June 2013, 1200[1]

Location Auckland

latitude: 37° 00’ 29” south

longitude: 174° 47’ 30” east

Injuries nil

Damage stabiliser trim control cable, pulley and drum damage

[1] Times in this report are NZ Standard Time (UTC +12 hours) and expressed in 24-hour format.

1. Executive summary

1.1. On 7 June 2013 a Boeing 737-838[2] operated by Jetconnect Limited was undergoing scheduled maintenance at Auckland International Airport. During an inspection of the forward electronics and equipment compartment area under the flight deck, metal filings were found next to the stabiliser trim[3] cable drum[4]. On closer inspection a rag was found trapped under the stabiliser trim cable windings on the forward cable drum.

1.2. The rag had made the cable windings bulge outwards, which caused the cables to contact the cable guides, creating the metal filings and damaging the guides. The rag had increased the cable tension of the stabiliser trim system, which resulted in damage to a number of cable pulleys through which it was rigged. The control cables had also started to wear through contact with the steel bolts that held the cable guide spacers in place.

1.3. The Transport Accident Investigation Commission (Commission) found that it was highly likely the rag originated from the Qantas Sydney maintenance hangar, and that the presence of the rag trapped in the cable drum windings compromised the integrity of the aeroplane's stabiliser trim system manual control.

1.4. This report also comments on a maintenance-related incident involving a Jetconnect aircraft that had undergone maintenance at the Qantas Melbourne maintenance hangar in September 2013. The Commission did not investigate that incident, but notes that, as with this incident, compliance with procedures during maintenance operations is important for aviation safety.

1.5. The key lesson learnt from the inquiry into this occurrence was that all personnel must take care not to leave anything behind inside an aircraft after completing maintenance or cleaning tasks, especially in areas or near systems critical to flight safety.

[2] A Boeing 737-800-model aircraft that was ordered by Qantas Airways Limited. The number 38 added at the end of the model number is the customer code for Qantas and stays with the aircraft for its entire service life.
[3] A flight control system that changes the angle of the horizontal stabiliser, which adjusts the amount of downwards or upwards aerodynamic force produced at the tail of an aircraft in flight. It is used to compensate for changes in centre of gravity and to maintain a wide range of airspeeds.
[4] Part of a closed-loop-control cable system that transmits the rotation movement of a drum through cable windings and along a cable run to another part of the control system, where it is converted into a linear or rotational output.

2. Conduct of the inquiry

2.1. The defect was identified by the maintenance organisation on 7 June 2013. The defect was recognised as an incident and verbally reported to the New Zealand Civil Aviation Authority (CAA) on 8 June. A written notification was made to the CAA on 17 June 2013. The CAA notified the Commission of the incident on 20 June 2013. On 21 June 2013 the Commission opened an inquiry under section 13 of the Transport Accident Investigation Commission Act 1990, and appointed an investigator in charge.

2.2. On 25 June two investigators from the Commission travelled to Auckland to inspect the damaged parts that had been removed from the aircraft, and to interview the airline's engineering and management staff.

2.3. The rag that had been retrieved from the cable drum was sent to the New Zealand Wool Testing Authority to determine the type of material from which it was made and how it had been manufactured.

2.4. The Commission sourced samples and photographs of the rags used by the companies that carried out maintenance on the Jetconnect Limited Boeing 737-838 fleet. These samples were compared to the rag retrieved from the cable drum.

2.5. At the Commission's request, the United States National Transportation Safety Board appointed an accredited representative[5] to facilitate the testing of the used rag by the aircraft manufacturer.

2.6. The used rag found under the cables was then sent to the aircraft manufacturer Boeing, to determine whether the rag could have been introduced onto the cable drum during the assembly of the aeroplane at manufacture in 2011.

2.7. The Commission was notified in September 2013 of another incident involving a Jetconnect B737-838 in Wellington, where a rag was found left on a landing gear wheel uplock mechanism after maintenance. This was investigated by the maintenance company together with the airline. The investigation report was reviewed by the Commission as part of this inquiry.

2.8. At the Commission's request the Australian Transport Safety Bureau appointed an accredited representative to carry out an inspection of the maintenance facility in Sydney, where a similar type of rag was used and where tasks had been carried out on the aircraft. On behalf of the Commission the accredited representative also conducted interviews with engineers who had worked on the incident aircraft.

2.9. On 19 November 2014 the Commission approved this report for circulation to interested persons for comment.

2.10. On 25 February 2015 the Commission approved this report for publication.

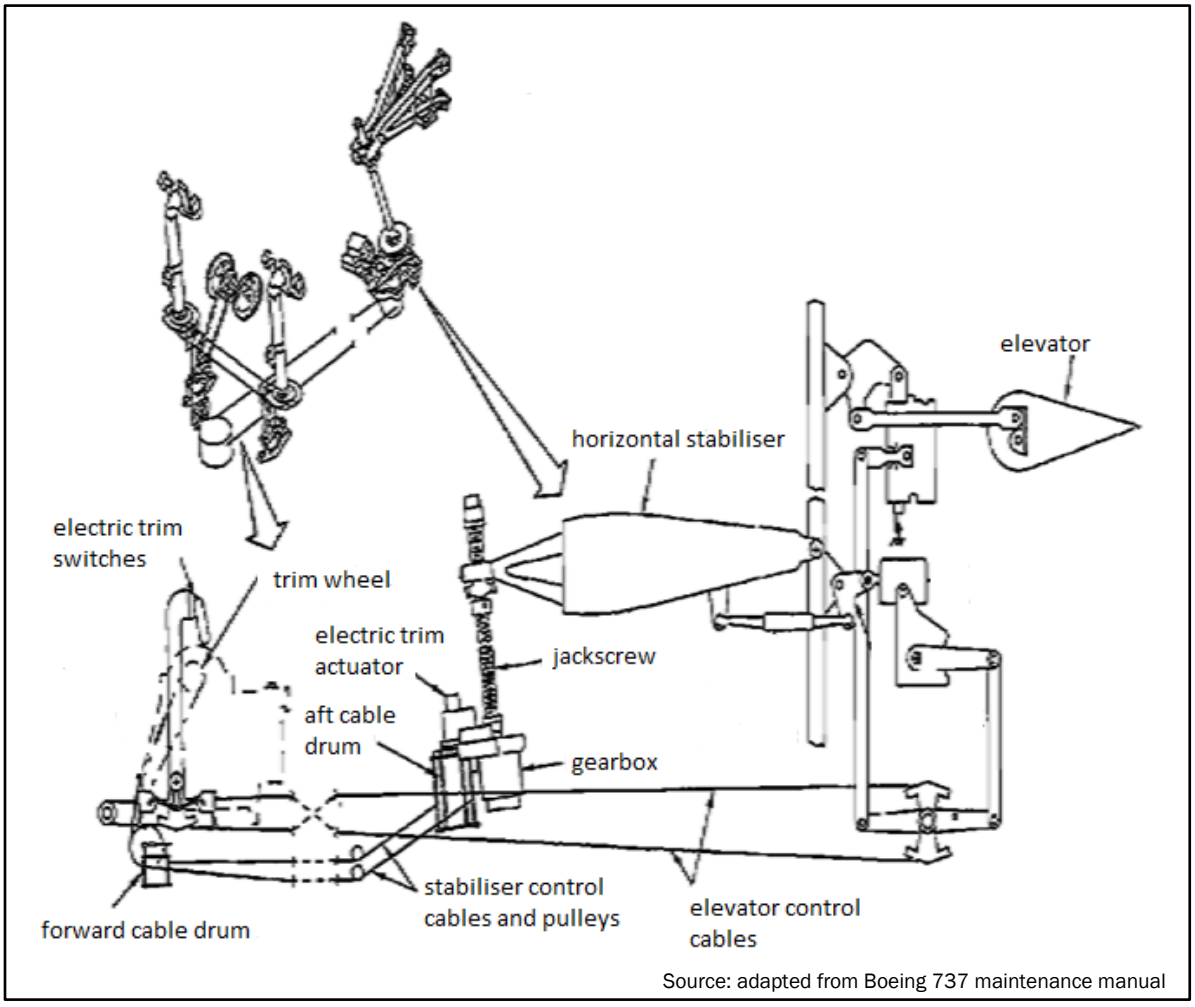
[5] As the State of manufacture of the aeroplane, in accordance with Annex 13 to the Convention on International Civil Aviation.

3. Factual information

3.1. Narrative

3.1.1. On 7 June 2013 a Boeing 737-838 aeroplane (registration ZK-ZQG) was undergoing an overnight inspection in a hangar at Auckland International Airport. The aeroplane was operated by Jetconnect. A maintenance engineer was making a routine visual inspection of the forward electronics and equipment compartment located under the flight deck when he discovered metal filings adjacent to the forward cable drum of the stabiliser trim system.

3.1.2. The stabiliser trim system on the B737 series aircraft consisted of a moveable horizontal stabiliser[6] on the tailplane, which was adjusted to trim the aeroplane aerodynamically in flight. Manual adjustment was achieved through a cable and pulley system between the trim wheel in the cockpit and a jackscrew[7] actuator that moved the stabiliser. The cables were wound onto two cable drums, one aft and one forward. The forward cable drum was located in the electronics and equipment compartment under the flight deck. A separate electric control system consisting of an electric motor actuator and control switches could be used to move the horizontal stabiliser independently of the manual system (see Figure 1 and the glossary for more detail).



Source: adapted from Boeing 737 maintenance manual

Figure 1
Schematic of B737 stabiliser trim system

[6] A fixed or movable aerodynamic surface on which pitch-control surfaces (elevators) are mounted. It provides stability in pitch, and can also be moveable for the purpose of trimming.
[7] A type of jack that converts the rotational input of a screw into a linear movement output (similar to a motor vehicle jack).

3.1.3. On further investigation the maintenance engineer found damage to the cable guides on the forward stabiliser trim cable drum. He found that a rag was trapped under the steel cable that was wound onto the cable drum (see Figure 2). The rag was causing the steel cable to bulge out from the drum and make contact with the aluminium spacer on the cable guide as the cable drum rotated. The metal filings he had initially noticed were from the softer aluminium spacer being worn by the steel cable.

3.1.4. In places the stainless steel cables had worn right through the aluminium spacer and had started to wear through the harder steel bolts that held the guide spacers in place (see Figure 3). The stainless steel trim cables themselves had begun to wear as a result. The situation had increased the tension on the trim cables, which had also damaged the cable pulleys that were located between the forward and rear cable drums.

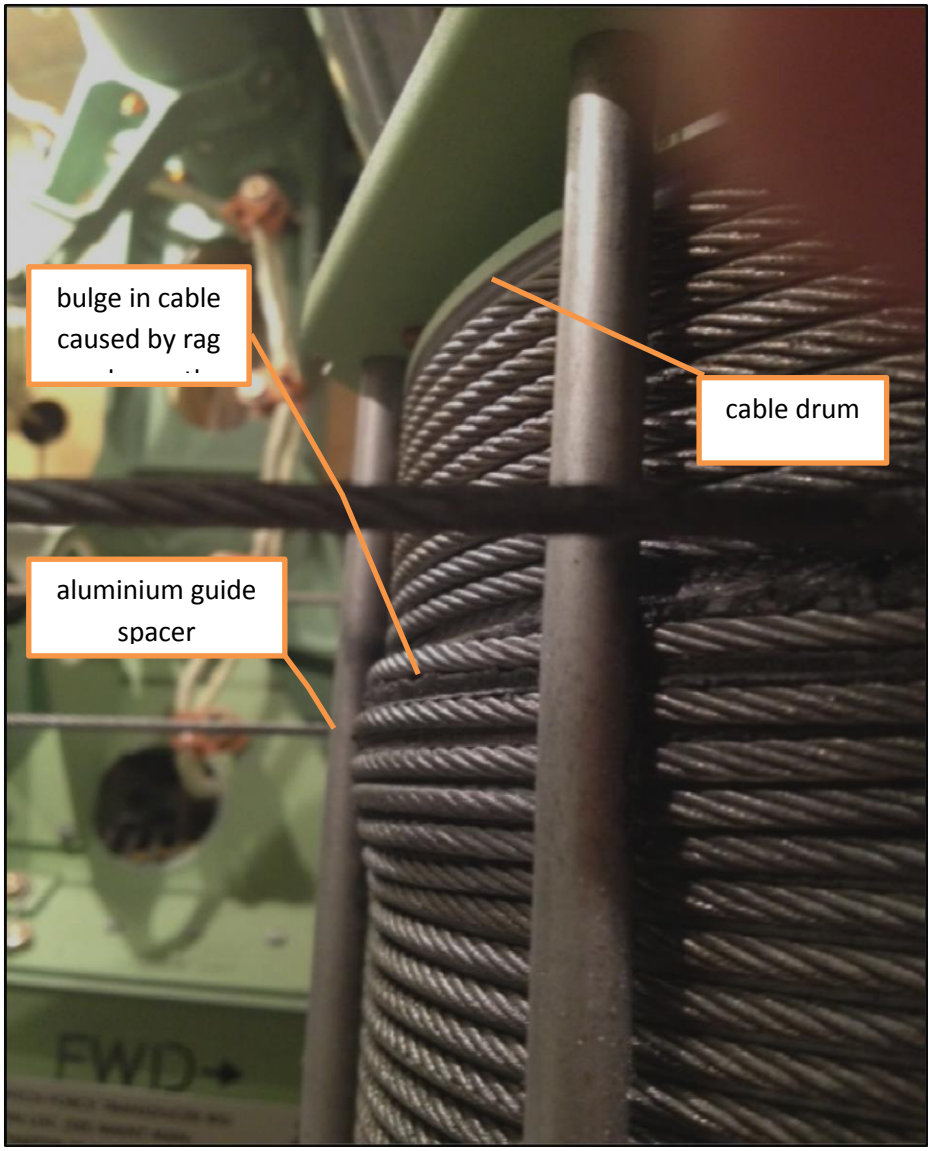


Figure 2
Photograph of forward cable drum

Figure 3
Cable guide steel bolt damage

3.1.5. Both trim cables, four cable pulleys and the forward trim cable drum were replaced with new parts. The trim system was then checked for correct rigging and normal operation before the aircraft was released for service.

3.2. Aircraft information

3.2.1. The Boeing 737-800 model aeroplane is a later variant of the B737 series of aircraft, which was originally introduced to service in the late 1960s. The B737 Next Generation models launched in 1993 included the B737-800 model, which had seating for up 189 passengers in a longer cabin, more powerful and fuel-efficient CFM-56 turbofan engines, larger wings and flight control surfaces, and new electronic flight deck displays. The flight control systems and stabiliser trim system had remained largely unchanged from the original B737 models designed in the early 1960s and the Classic models introduced in the 1980s.

3.2.2. The aeroplane involved in this incident was built in early June 2011 and delivered to Qantas later that month. A pre-service inspection was carried out in Melbourne, and equipment that was required on board to enter passenger revenue service was fitted, before it was accepted by its new operator Jetconnect, a New Zealand-based subsidiary of Qantas. It was then used to carry passengers between New Zealand and Australia for the two years prior to June 2013, logging approximately 7223 flying hours and 2352 flight cycles during this time.

3.3. Tests and research

3.3.1. The rag recovered (see Figure 4) from the cable drum was sent to the New Zealand Wool Testing Authority for analysis, to determine the type of material, method of manufacture and, if possible, where it was made.

3.3.2. The Commission requested descriptions and photos of the types of rag used by each of the maintenance facilities that had performed scheduled maintenance tasks on the aircraft. All maintenance facilities used recycled cloth rags, and only the Sydney facility used paper towel type rags.

3.3.3. The used rag was also sent to Boeing to be tested by its Research and Technology department, to determine whether it was the same type of rag used in the production of the aircraft. A test report, which was reviewed by the National Transportation Safety Board Accredited Representative, concluded that the "rag was not consistent with examples used in production" at Boeing. Measurements made under a microscope showed that the weave pattern was different, and chemical analysis results determined that the fibre composition was dissimilar to examples from the production facility.

3.4. Other incident

3.4.1. On 11 September 2013 a Jetconnect B737-838, registration ZK-ZQC, was involved in an incident that occurred during a flight to Wellington. The aeroplane had departed from Melbourne, where it had recently had maintenance carried out on the landing gear. After departing Melbourne the flight crew had difficulty raising the right main landing gear. The right main landing gear initially retracted but did not stay up, falling back down once the gear selector was moved to the off position. When the crew reselected the gear lever to the up position, the right main gear retracted and stayed up. After the aeroplane landed at Wellington the ground engineers inspected the landing gear and found a rag wrapped around the right main landing gear uplock assembly.

3.4.2. Qantas Airways had performed the maintenance task in Melbourne and also operated the maintenance facility in Sydney. It conducted a safety investigation into the second incident, which found that the rag had been used by an engineer to protect against an accidental head strike on the uplock during a maintenance task in the right main wheel well area. The rag was subsequently left on the uplock assembly after the maintenance task was completed, and it interfered with the retraction of the right main landing gear during the next flight.

4. Analysis

4.1. Foreign objects left inside an aircraft and around safety-critical components such as flight control systems are a threat to the safe operation of the aircraft. Loose articles can move inside an aircraft and become trapped under moving components, such as control cables and levers. These foreign objects can disrupt the normal operation of aircraft systems and damage system components, which could fail at a later stage.

4.2. In this case the rag had become trapped on the cable drum, resulting in damage to the cable, the cable drum guides and the pulleys through which the cable passed between the forward and aft cable drums. Whilst considered unlikely, there was the potential for the stabiliser trim system manual control to become jammed or at worst disabled if a cable severed. However, the electric side of the stabiliser trim system control, consisting of an electric motor actuator that moved the stabiliser directly through a gearbox and clutch, would have still operated through independent electric switches on the pilots' control column[8] (wheel). As a result, there would have been no feedback through the manual control cable to move the trim indicator[9] during the operation of the electric system, although the pilot would have retained control.

4.3. Three ways in which a rag could end up in the electronics and equipment compartment were considered:

- it had been there since aircraft manufacture
- it had been carried into the compartment by an engineer conducting routine inspection and maintenance
- it had migrated into the compartment from the flight deck (through gaps behind the rudder pedals) after being left there.

4.4. The Boeing manufacturing process involves numerous inspections and quality-control processes that would normally prevent the aeroplane being delivered with a rag left in a compartment where safety-critical systems were located. The operator also conducted its own acceptance and pre-service inspections after delivery from the manufacturer. The cloth was not of the same size or type used by Boeing during its manufacture process. For these reasons, it is unlikely that the rag had been left in the compartment during manufacture.

4.5. The Commission obtained samples of all the rag types in use at the three scheduled-maintenance facilities where the aircraft had been serviced. A comparison of each type was made with the rag found trapped on the cable drum. The rags used at Melbourne and Auckland came from recycled clothing and bed sheets cut up into smaller pieces for use. The Sydney maintenance facility used commercially available, disposable paper-type wipes that came either on a roll or as pre-cut square pieces in a box dispenser. Five different types of cleaning rag were in use at Sydney. One of them was a 300-millimetre-wide roll with tear-off perforations every 340 millimetres, which closely matched the size and texture of the cloth found on the forward cable drum. Rag samples were not sought from commercial cleaning companies that cleaned the interior of the aircraft at airport terminals, due to the fact that they were not allowed to enter the flight deck or electronics and equipment compartment.

4.6. A sample (see Figure 5) from this roll and the incident rag were sent to the New Zealand Wool Testing Authority for comparison. The fibre content was assessed using chemical dissolution tests. The test report[10] showed that both samples were made from a cellulosic or paper-based fibre and polypropylene. The frequency and position of the needling marks made during manufacture were compared and the samples matched. The test report concluded that it was "very likely that the two cloths [rags] are the same" and that "the crease pattern in the cloth [rag] is consistent with the cloth [rag] having been caught and dragged".

[8] A control column is used by the pilot in conjunction with other controls to change direction and altitude.
[9] The indicator is located in the flight deck, and shows the pilot the position of the horizontal stabiliser.
[10] New Zealand Wool Testing Authority report No. 13/584B.

4.7. The findings of the New Zealand Wool Testing Authority and the fact that the Sydney maintenance facility was the only one where that type of rag was used, make it highly likely that the rag found trapped on the forward cable drum originated from the Sydney hangar.

4.8. The aircraft maintenance history was reviewed to establish when the rag had been trapped on the forward cable drum. However, this was not possible to determine, and no significant maintenance had been performed on the stabiliser trim system prior to the occurrence.

4.9. There are a number of maintenance and cleaning tasks carried out in the flight deck area and in the electronics and equipment compartment. It was not possible to determine when a rag may have been introduced into either the flight deck or the electronics and equipment compartment, because the use of rags was not required to be controlled or recorded.

4.10. Several aircraft system components and control units are located in the electronics and equipment compartment. Consequently there are many tasks carried out during routine aircraft servicing and maintenance that require engineers to enter the compartment and work in the area around the stabiliser trim cable forward drum. It is possible that an engineer carried a rag on them while working near the trim cables, which was either left behind or dropped and later became drawn onto the forward cable drum and under the cable windings.

4.11. The type of rag involved was used for internal cleaning and made from a lint-free material, which meant one of its main purposes was cleaning the inside of the flight deck windscreens. The windscreen cleaning was normally done as required by maintenance engineers, and it was not normally recorded when this task was carried out. It was possible for a rag used for windscreen cleaning to be dropped on the floor near the rudder pedals, which could have migrated through the gaps behind the rudder pedals and down into the electronics and equipment compartment below, and drawn under the cable windings of the forward drum.

4.12. This incident, and the one that caused the landing gear retraction problems on the B737-838 departing Melbourne, highlight the importance of good housekeeping during maintenance operations. In both cases a rag left inside the aircraft caused a safety issue with a system that was critical for flight.

4.13. A final inspection after all work has been completed and before the aeroplane is returned to service is generally accepted best aeronautical engineering practice for ensuring that nothing has been left behind that could affect the integrity of critical aircraft systems. The addition of a recorded inspection at the end of each work task or maintenance hangar visit helps to ensure that this foreign object check is done thoroughly every time certain critical areas have been accessed. Despite these measures being in place at the maintenance facilities, rags were left in the aircraft.

4.14. These incidents reinforce the need for thoroughness when carrying out these inspections at the completion of maintenance. Procedures developed to prevent foreign objects being left behind after maintenance must be adhered to in order to avoid similar incidents occurring in the future.

Findings:

1. The integrity of the aeroplane's stabiliser trim system manual control was compromised by a rag that became trapped under a control cable that was wound onto the forward cable drum of the stabiliser trim system.

2. It was highly likely that the rag ended up in the aeroplane's electronics and equipment compartment following cleaning, inspection, or maintenance conducted at the Qantas Sydney maintenance facility.

5. Findings

5.1. The integrity of the aeroplane's stabiliser trim system manual control was compromised by a rag that became trapped under a control cable that was wound onto the forward cable drum of the stabiliser trim system.

5.2. It was highly likely that the rag ended up in the aeroplane's electronics and equipment compartment following cleaning, inspection, or maintenance conducted at the Qantas Sydney maintenance facility.

6. Safety actions

General

6.1. The Commission classifies safety actions by two types:

(a) safety actions taken by the regulator or an operator to address safety issues identified by the Commission during an inquiry that would otherwise result in the Commission issuing a recommendation

(b) safety actions taken by the regulator or an operator to address other safety issues that would not normally result in the Commission issuing a recommendation.

Safety actions addressing safety issues identified during an inquiry

6.2. No safety actions were identified.

Safety actions addressing other safety issues

6.3. None identified.

7. Recommendations

General

7.1. The Commission may issue, or give notice of, recommendations to any person or organisation that it considers the most appropriate to address the identified safety issues, depending on whether these safety issues are applicable to a single operator only or to the wider transport sector.

7.2. In the interests of transport safety it is important that these recommendations are implemented without delay to help prevent similar accidents or incidents occurring in the future.

Recommendations

7.3. The safety issues identified during this inquiry have been addressed in the “Analysis” and “Key lesson” sections of this report. No recommendations were made as a result of this inquiry.

8. Key lesson

8.1. All personnel must take care not to leave anything behind inside an aircraft after completing maintenance or cleaning tasks, especially in areas or near systems critical to flight safety.

Appendix 1: Rag samples

Figure 4
Incident rag

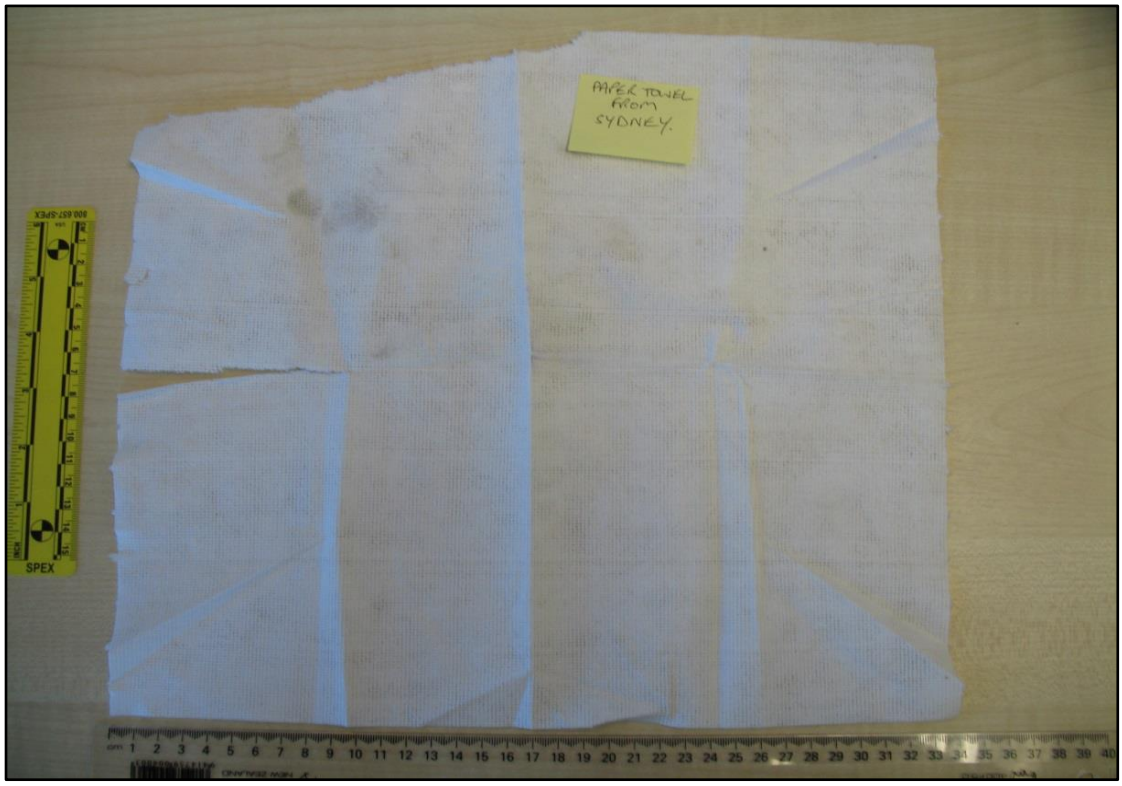


Figure 5
Unused rag sample

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10-009	Walter Fletcher FU24, ZK-EUF, loss of control on take-off and impact with terrain, Fox Glacier aerodrome, South Westland, 4 September 2010
10-007	Boeing 737-800, ZK-PBF and Boeing 737-800, VH-VXU airspace incident, near Queenstown Aerodrome, 20 June 2010
10-005	Cessna A152, ZK-NPL and Robinson R22 Beta, ZK-HIE near-collision. New Plymouth Aerodrome, 10 May 2010

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