NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

December 21, 2016

Factual Report of Systems Group Chairman

A. ACCIDENT:	ERA15LA140
Location:	Marco Island, FL
Date:	March 1, 2015, 16:15 EST
Aircraft:	Bombardier CL-600-2A12, N600NP[1]

B. GROUP MEMBERS:

Group Chairman:	Robert L. Swaim National Transportation Safety Board Washington, DC
Member:	Jimmy Avgoustis Bombardier Montreal, Canada
Member:	Kevin Kurko Meggitt Aircraft Braking Company Akron, Ohio
Member:	Rich McKenna Goodyear Stockbridge, Georgia

C. SUMMARY:

On March 1, 2015, about 1615 eastern standard time, a Bombardier CL-600-2A12 (CL-601), N600NP, registered to and operated by Six Hundred NP, LLC, experienced a landing overrun and subsequent collapse of the nose landing gear at Marco Island Airport (MKY), Marco Island, Florida. The two pilots, a flight attendant, and four of the six passengers were not injured; of the remaining two passengers, one sustained a serious injury and one sustained minor injuries. The airplane sustained substantial damage. The flight originated about 1554 est, from The Florida Keys Marathon Airport (MTH), Marathon, Florida , and was conducted as an executive / corporate flight under the provisions of 14 Code of Federal Regulations Part 91. An instrument flight rules flight plan was filed, and visual meteorological conditions prevailed at the time of the accident.

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[1] Manufacturer serial number 3002

The physical parts submitted for examination were the #1 tire, the #1 anti-skid braking system wheel speed sensor (WSS), and a broken spring from the #2 brake control valve (BCV).[2] A broken plastic coupling was found within the #1 anti-skid WSS. This report relates factual information pertaining to the function of the parts.[3]

The Investigator In Charge (IIC) also provided photographs, parts, and data for examination and analysis. These included a set of notes created on-scene which described the runway, airplane examinations, photographs of the tires, photographs of the runway with orientations, photographs of damage to the airplane, pilot statements, and the results of testing performed after the accident.

Items found during this investigation have resulted in FAA generation of three internal safety recommendations regarding potential failures of Brake Control Valve (BCV) springs manufactured by Tactair, development of a Special Airworthiness Information Bulletin to alert inspectors and owner/operators, and calling on Bombardier to develop a related service bulletin. Action is pending further coordination between the FAA and Transport Canada.

D. DETAILS OF THE INVESTIGATION

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OPERATION, BACKGROUND, AND RUNWAY MARKINGS:

The Airplane Flight Manual contains the following procedure for landing.[4]

20. LANDING PROCEDURE

[2] The four main landing gear tires and brake systems are numbered from left to right. The left outboard is #1, left inboard is #2, right inboard is #3, and right outboard is #4.

[3] The #2 BCV spring and #1 anti-skid coupling were each examined by the NTSB Materials Laboratory, where separate reports were created to describe the fractures.

[4] Model CL−600−2A12 Airplane Flight Manual PSP 601−1B−1, NORMAL PROCEDURES, Page 56B-57, Revised Oct 26/09

Approach through 50 feet height point at speed of 1.3 V_S (refer to PERFORMANCE − LANDING) on stabilized glideslope of 3 degrees with gear down and flaps at 45 degrees.[5]

Thrust reversers may be used after touchdown to supplement the use of wheel brakes.

CAUTION

> With thrust reversers deployed, a nose-up pitching tendency will occur at high power settings, particularly at aft center of gravity light weights. This tendency is controllable with elevator and may be minimized by ensuring that nose wheel touchdown is achieved and nose down elevator applied, before selecting reverse thrust.

A. PROCEDURE

(1) Continuous ignition . . . As required	refer to LIMITATIONS − OPERATING LIMITATIONS.
(2) Thrust levers . . . . Reduce	to IDLE at 50 feet.
(3) Airplane attitude . . . . Maintain	until close to runway. Perform partial flare and touchdown without holding off.

NOTE

> If icing accumulation on the wheels and brakes is suspected, carry out a positive landing to ensure initial wheel spin up and breakout of frozen brakes.

(4) Flight spoilers . . . . Extend	immediately after main wheel touchdown.[6]
(5) Wheel brakes . . . . Apply	as soon as possible.
(6) Maximum braking . . . . Maintain	until safe stop on runway is assured.

(7) Thrust reverse

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[5] V_S Denotes stall speed at 1G, which is shown on the airspeed indicator as and end of a green band.

[6] The ground spoilers do not automatically deploy on this aircraft. In accordance with the 601 AMM (PSP 601-2) section 27-61-00 section 2. B. "The ground spoilers are armed for deployment at touch-down by setting the ground spoilers switch to the ON position and moving the spoiler control lever to the EXTEND position." Aircraft serial no. 3060 or higher or aircraft incorporating Bombardier service bulletin 601-0113 auto deploy the ground spoilers after the logic is made and WOW or spin up. Bombardier has no record of this service bulletin incorporated on this aircraft.

levers . . . . Lift and pull — back to hold gently against baulk.

When baulk releases (REVERSE THRUST light on):

(8) Thrust reverse levers . . . . Pull — back to required thrust setting.

(9) Rudder and aileron . . . . Use — as required, to maintain directional control.

When speed falls to 60 KIAS:

(10) Thrust reverse levers . . . . . . Adjust — to reduce reverse thrust to 60% N_1 or below.

(11) Nose wheel steering . . . . Use — as required.

The last landing had been at Florida Keys Marathon International Airport (KMTH) where the runway is almost exactly the same length as where the accident occurred at Marco Island airport. The Captain did not report reduced braking or pulling to one side at Marathon, and reported nothing abnormal about use of the ground spoilers or thrust reversers. After landing at Marco Island, the Captain said that he did not feel the normal deceleration with the use of "moderate" brake pressure, so he released the brakes and turned off the anti-skid, then re-applied the brakes manually.

In post-accident testing, the #2 brake system did not operate and a broken spring was found in the related BCV. (The #1 brake anti-skid WSS which contained a broken plastic coupling is discussed later in this report.) By exchanging parts between the four brake systems, each of the systems functioned when the spring and parts broken by the accident were replaced.

The Captain also said that he was unable to move the ground spoiler and thrust reverser controls.[7] The on-scene portion of the investigation documented that the ground spoilers and thrust reversers were functional. Further, the post-accident testing included verification that the air/ground logic of the landing gear control unit (LGCU) was functional.

The Marco Island runway path of the airplane could be followed as damage to the off-runway surface and on-runway black rubber transfer marks from the resting position of the airplane to the area of landing. Following the black marks toward the arrival end of the runway, the tire markings merged into the overall black area of the runway which had been created by the landings of many airplanes. Photographs of the discernable tire paths closest to the arrival end of the runway revealed that the left two tires differed from the right two tires. The examination revealed black rubber transfers from three of the four tires, with little transfer from the #2 tire. (See Figure 1)

[7] The Investigator In Charge documented at Marco Island that the spoilers and thrust reversers were tested with Bombardier and found operational after the accident.

In the direction of travel, the #1 tire tread runway markings initially showed the drainage grooves in the tread, then a solid black width of the tire where the worn area was deeper than the grooves, followed by the end of the continuous tire mark where the tire shoulders moved apart, followed by flail marks (alternating dark/light) consistent with the deflated tire on the pavement. (See Figure 2)

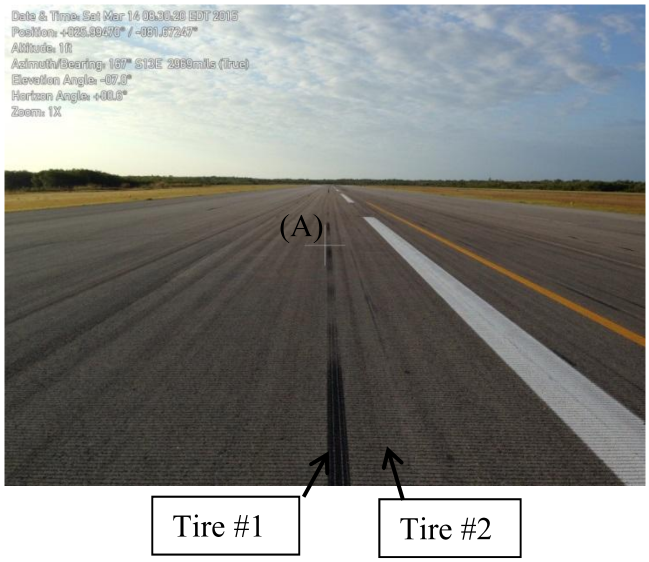

Figure 1. Rubber tire transfer marks on runway in direction of travel. Two individual rain grooves in the#1 tire transfer are visible at the bottom edge of the photo. The arrow denotes the path of the #2 tire and lack of black braking rubber transfer to the runway. The point (A) is detailed in Figure 2.

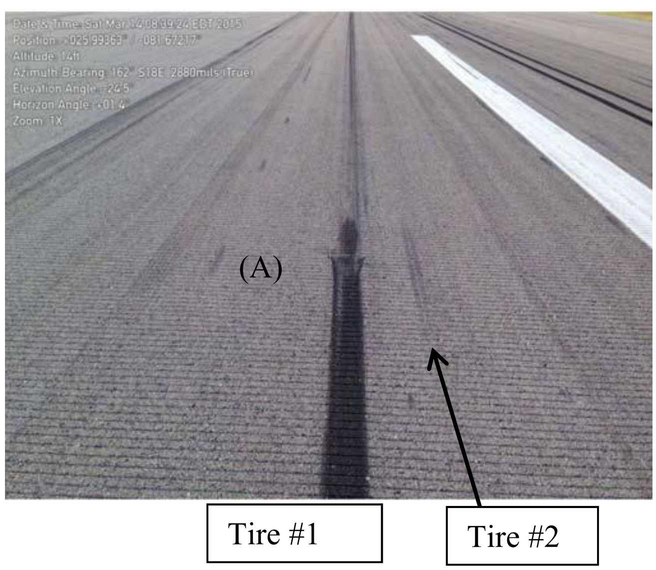

Figure 2. View depicting the changes in rubber transfer marks from the #1 and #2 tires. The (A) corresponds with Figure 1. The mark in the #2 track is consistent with the airplane weight supported by tire #1shifting to tire #2. At the bottom of

the photo the #1 tire rain grooves visible in Figure 1 no longer exist. The tire examination showed that the rain grooves remained in all but the flat spot of the tread where the cross-shaped blow out existed.

Tire #2 was the only tire which remained inflated and the rubber transfer from it at the departure end of the runway continued to be lighter than the marks made by the other tires. (See Figure 3) Tires #1 and #4 tire shoulder rubber transfers appeared as dark parallel lines on the runway, without rubber transfer from the centers of the treads, consistent with a lack of pressure. The Captain stated that "I applied full right rudder in an attempt to keep the airplane on solid ground." Bombardier noted that the rubber transfer left by the nose landing gear tires indicated that the steering system was operational because the nose landing gear is designed to freely caster when inoperative, and that castering would not leave a rubber skid mark.

Figure 3. Marks made by all main landing gear tires at departure end of runway. Since this view is backward along the path, the marks are for Tire #4 at the left and Tire #1 at the right. Inboard of the #3 tire transfer was a rubber transfer that was consistent with the nose landing gear (NLG). Photograph provided by the IIC.

The Captain stated that the airplane required a landing distance of 3,166 feet and the landing target was 1,000 feet from the approach end of the 5,000 foot runway.[8] The Bombardier Airplane Flight Manual which provided this estimate was based upon (1) landing on the target, (2) at a specific speed, and (3) use of maximum braking force which required the use of the anti-skid braking system. The Bombardier AFM showed that deviation from any of these criteria lengthens the landing distance and subtract from the 834 foot margin.

The AFM PERFORMANCE – LANDING section provides operational information about landing distances. The list of baseline (termed "associated") conditions does not include the use

[8] Citations from the pilot and other statements and other operational material are cited for context and additional information may be found in the Investigator In Charge report about aircraft operations. In case of differences, the Investigator In Charge report about aircraft operations takes precedence.

of thrust reversers. The section (page 165) does provide the following relations between how the operation of various systems affects landing distances.

1. In discussing the results of stall protection system failures the AFM notes that distance increases 15% (1.15 X 3,166 feet = 3,641 feet) for an additional 2.5 knots and 20% for 10 knots.

   Note: 1.15 X 3,166 feet = 3,641 feet
   1.20 X 3,166 feet = 3,800 feet

2. If retracting flight spoilers is not possible, the AFM states that an extra 10 knots must be used for landing and that the landing distance would increase 30%.

   Note: 1.30 X 3,166 feet = 4,115 feet

3. The inability to deploy flight spoilers increases the as-shown landing distance by 15%.

   Note: 1.15 X 3,166 feet = 3,641 feet

4. Deflation of the #1 tire and failure of the #2 BCV spring resulted in loss of half of the wheel brakes. Loss of half brakes is addressed by the AFM in the statement: “Half-failure of the wheel brakes (loss of pressure in No. 2 or No. 3 hydraulic systems) increases actual landing distance by a factor of 1.50 (50%).” Potential resutls from the loss of both wheel brakes on only one side of the airplane is not addressed.

   Note: 1.50 X 3,166 feet = 4,750 feet

5. The Captain stated that he switched off the anti-skid system which is addressed by the AFM in the statement: “If it is necessary to switch off the anti-skid due to partial anti-skid failure (brake pressure normal), actual landing distance is increased by a factor of 1.45 (45%).”

   Note: 1.45 X 3,166 feet = 4,590 feet

Bombardier pointed out that the Airplane Flight Manual (AFM) provides landing distance additives for certain abnormal configurations that can be summed up by the flight crew prior to landing. Combinations of specific conditions are not shown for a combination of failure of the #2 BCV spring, spoilers not deploying, switching off the anti-skid, and deflation of the #1 tire.

BRAKING, GENERAL:

The airplane is equipped with four separate anti-skid braking systems which function independently, each monitoring the braking of other wheels for cues about activation, performance, and fault recognition. Each tire/wheel/brake assembly provides a quarter of the total stopping force in the four-tire set.

Each pilot has a left and right brake pedal and the sets are mechanically linked at the brake control assembly located beneath the cockpit floor. (See Figure 4)

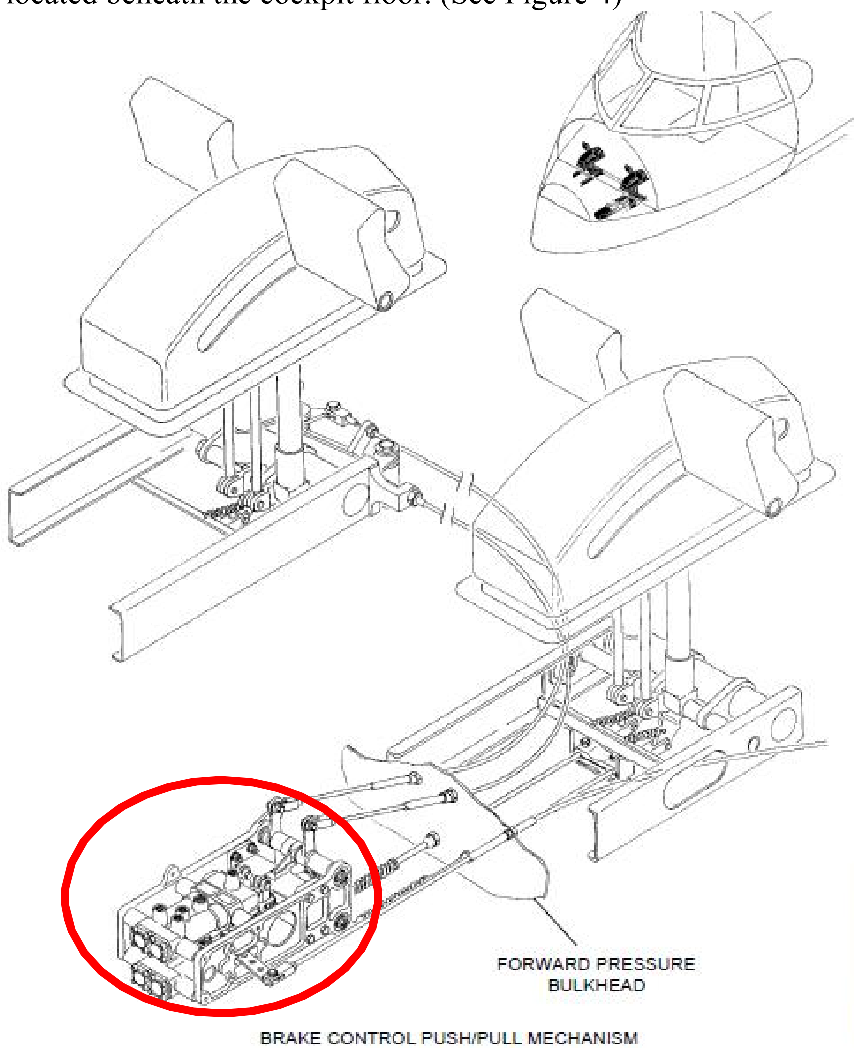

Figure 4. Airplane Maintenance Manual illustration shows location of the brake control components in the nose of the airplane. The broken spring was on one of the two brake control valves in the circle. Specifically, Bombardier noted that the broken spring was on the upper outboard brake control valve, controlling the inboard left (#2) brake. The #3 hydraulic system supplies the left and right inboard brakes and th e#2 hydraulic system supplies the outboard brakes.

Within the brake control assembly are two brake control valves (BCV), where the mechanical inputs manipulate hydraulic valves. Each of the four valves regulate the amounts of hydraulic pressure provided to each of the four wheel brake systems, through the anti-skid braking system and hydraulic fuses.[9] (See Figure 5)

[9] The hydraulic fuse stops the flow of hydraulic fluid to the brake unit if there is a leak in the hydraulic line.

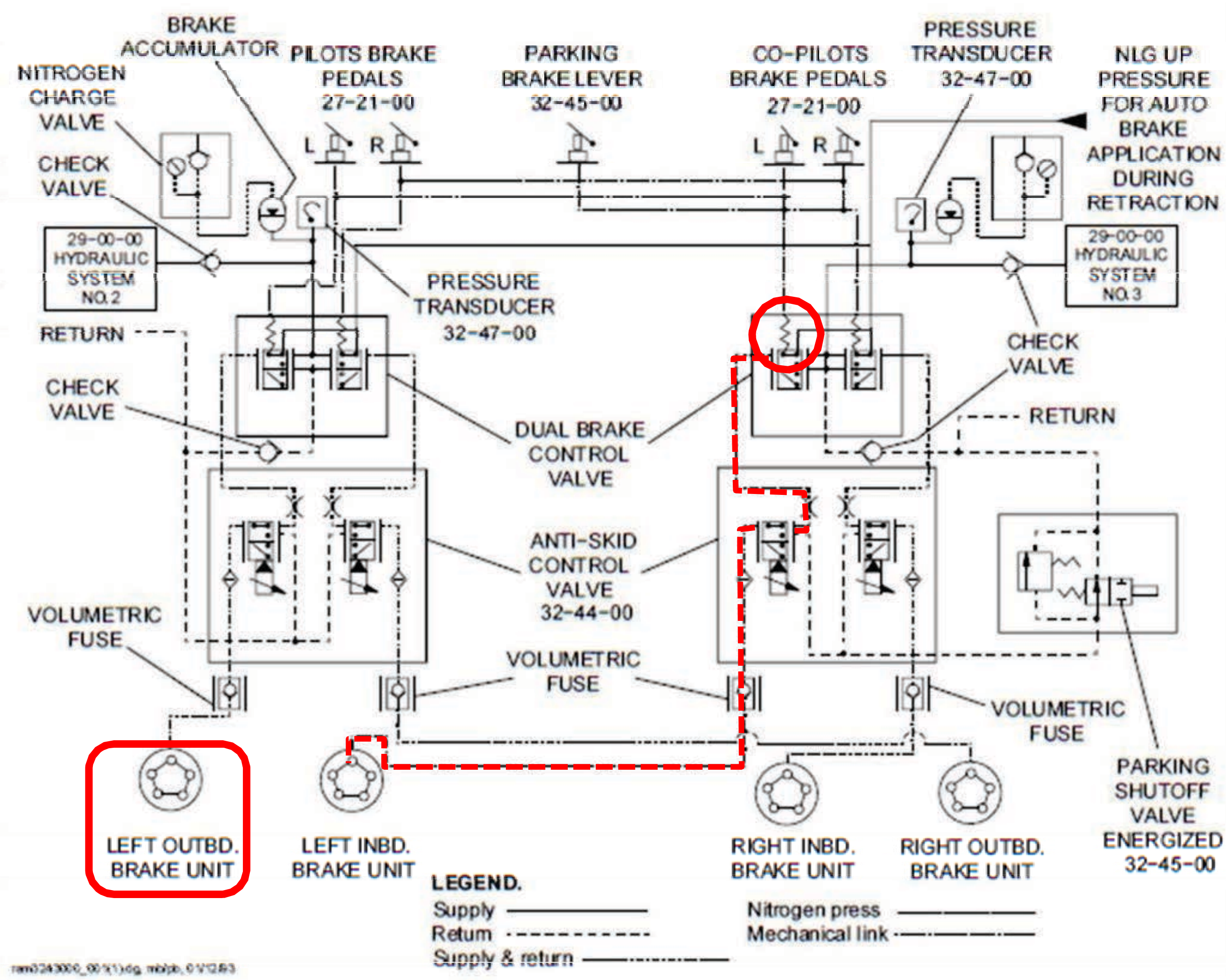

Figure 5. Airplane Maintenance Manual functional schematic of the braking system. The spring found broken is circled. The route from the dual brake control valve to the left inboard brake unit is a dashed line. Separately, the square in the lower left was the location of the broken plastic anti-skid coupling.

The two brake control valve (BCV) assemblies are installed in the nose hydraulics compartment as a part of the brake control mechanism assembly. The upper BCV controls the inboard brakes and is supplied by hydraulic system #3. Hydraulic system #2 supplies hydraulic pressure to the lower BCV, which controls the outboard brakes.

Each BCV assembly contains two valves. The inboard valves are actuated by the right brake pedals and the outboard valves are actuated by the left brake pedals. These valves are mechanically activated and hydraulically operated. The brake control valve assemblies get the mechanical force from the pilot's pedals through the brake control push/pull mechanism and let the hydraulic fluid flow to the antiskid control valves.

Within the mechanical portion of each control path of each system is a spring (four total) which is a link between the input of the brake pedal and the output hydraulic pressure from the valves that make each of the four wheel brakes function. The BCV input rods and the springs are not visible during preflight inspections, and the airplane is not designed to provide annunciations related to the integrity of the springs or other internal components.[10]

BRAKE TESTS AND FINDINGS:

During the onsite investigation, the brakes and anti-skid system were tested by the IIC with Bombardier support. Brake panel # 1 indicated 1,850 psi, brake panel # 2 indicated 150 psi, brake panel # 3 indicated 2,000 psi, and brake panel # 4 indicated 2,000 psi. The parking brake was checked on brake # 2 with the hydraulic line cross fed from the # 3 hydraulic system and brake panel # 2 indicated normal pressure (1,800 psi). The parking brake does not normally bypass the anti-skid valves. The anti-skid de energizes the anti-skid solenoid valve and also traps pressure from the #3 hydraulic return.[11]

With the selection of normal braking to include the BCV valves, the brake pressure test panel gauge showed 150 psi for the #2 brake when the other three brakes were at 1,850-2,000 psi. No faults were reported by the IIC to have been found in the post-accident testing of the system other than the broken spring in the upper outboard BCV for the #2 wheel brake, and the broken #1 wheel speed sensor.

The #1 and #2 wheel brakes were tested on-site and reported to function. The #3 and #4 wheel brakes were removed for examination at the NTSB in Washington, DC, and then testing at the manufacturer, Meggitt Aircraft Braking Systems. The #3 and #4 brake housings were removed for examination at Meggit because each had been sufficiently damaged by sliding along the runway that they could not be pressurized for testing. Disassembly found that remaining pad material existed and nothing indicated that the brakes would not function if hydraulic pressure could be applied.

The brake control valve (BCV) assemblies are made by Tactair Fluid Controls (Tactair) for Bombardier CRJ and Challenger airplanes under different valve part numbers. According to Tactair, the two valves have “some differences, but operationally, they are essentially the same.” Tactair reported that more than one spring “was found broken” (relaxed springs not mentioned) in service in the CRJ series of airplanes (P/N HP1333200-) and provided service record data pertaining to P/N HP1333100- valves which had been installed in Challenger 601 airplanes. (See Table 1) All broken or relaxed BCV springs were replaced and the units were returned to service.

[10] The springs are only visible after the valve is disassembled, which typically requires the valve to be sent to the valve manufacturer.

[11] According to the IIC “the No. 2 brake line at the brake metering valve was positioned onto the port for the No. 3 brake and the #3 hydraulic system was pressurized and normal pressure (2,000 psi) was noted at the #2 brake.”

HP1333100 Series Brake Control Valve Repair/Over-Haul History				
Part Number	**Repair/Over-Hauls**	**Units w/ Broken Springs**	**Units w/ Relaxed Springs**	**Comments**
HP1333100-1	0	0	0	
HP1333100-3	14	0	0	
HP1333100-5	14	**1**	0	
HP1333100-7	0	0	0	
HP1333100-9	260	**1**	**37**	Investigation unit (S/N 1025)
HP1333100-11	87	0	**6**	
HP1333100-13	10	0	0	
Totals:	**385**	**2**	**43**	

Table 1. Tactair service record data

Bombardier conducted a safety risk assessment and found that the loss of one or two brakes on the same side would result in a low risk condition from what the company stated was from a continuing airworthiness type certificate perspective of the Challenger 601 fleet.[12] In response to questions regarding assumptions and the definition for "Low Risk," Bombardier provided the following:

> The brake control system was originally certified considering a brake control valve power brake spring fracture being dormant. It was assumed that a loss of one brake would be self-evident to the flight crew after a hard braking that can be expected every 5 landings. This condition will produce asymmetrical braking (pulling to one side) and result in the flight crew reporting the condition to their maintenance provider for unscheduled maintenance of the brake system.
>
> Loss of one (1) brake (any side):
> For certification purposes, the hazard severity is required to be "minor" and the hazard probability is required to be $\leq 1X10^{-3}$ (Probable).
>
> For this case, the Bombardier calculated hazard probability is $1.99X10^{-7}$ (remote) with respect to the dormant failure and therefore, this is a low risk condition. Furthermore, the low risk condition has sufficient margins to sustain a theoretical 1,000 hrs of dormancy. It is to be noted that the benefit of this 1000 hour theoretical limit calculation is to form a datum for what is considered to be the theoretical maximum to remain in low risk. Brake control system was originally certified considering a brake control valve power brake spring fracture being dormant. It was assumed that a loss of one brake would be self-evident to the flight crew after a hard braking that can be expected within the next 5 landings. This condition will produce asymmetrical braking (pulling to one side) and result in the flight crew reporting the condition to their maintenance provider for unscheduled maintenance to the brake system.
>
> Loss of two (2) brakes on same side:

[12] Inspection of the brake control mechanism with the BCVs is part of a zonal inspection program. The inspection does not require or direct a mechanic to note the symmetric length of the rods, which could be an indication of a broken or relaxed spring

For certification purposes, the hazard severity is required to be "hazardous" and the hazard probability is required to be $\leq 1X10^{-7}$ (Extremely Remote).

For this case, the Bombardier calculated probability is $7.92X10^{-8}$ (Extremely remote) and therefore this is a low risk condition.

The Bombardier position is that the company has determined that no changes to the design or the scheduled maintenance program are required as the probability of the loss of two brakes on the same side is extremely remote.

ANTI-SKID BRAKING SYSTEM

As shown in Figure 5, the airplane is equipped with a wheel brake anti-skid control system. The anti-skid braking system does not allow the brakes to pressurize upon landing to prevent landing with a tire which will not rotate and then modulates hydraulic pressure until the wheelspeed(s) have decreased or when a pilot turns the system off.

The AFM landing procedure calls for the pilot to press fully on each pedal immediately to utilize the anti-skid and that the pilot must maintain the pressure on the brake pedals until the airplane comes to a stop. There is not a standard or objective definition for "moderate" in the Bombardier Challenger documentation, as described by the Captain, and the anti-skid control selections are ARM, OFF, TEST, with no "MODERATE" option. (See Figure 6)

The Captain stated that he did not feel deceleration with the use of "moderate" brake pressure, so he released the brakes and turned off the anti-skid, then re-applied the brakes pressing hard.[13]

[13] Bombardier also provided a braking performance report after the accident, FS-2015-601-001-DP.

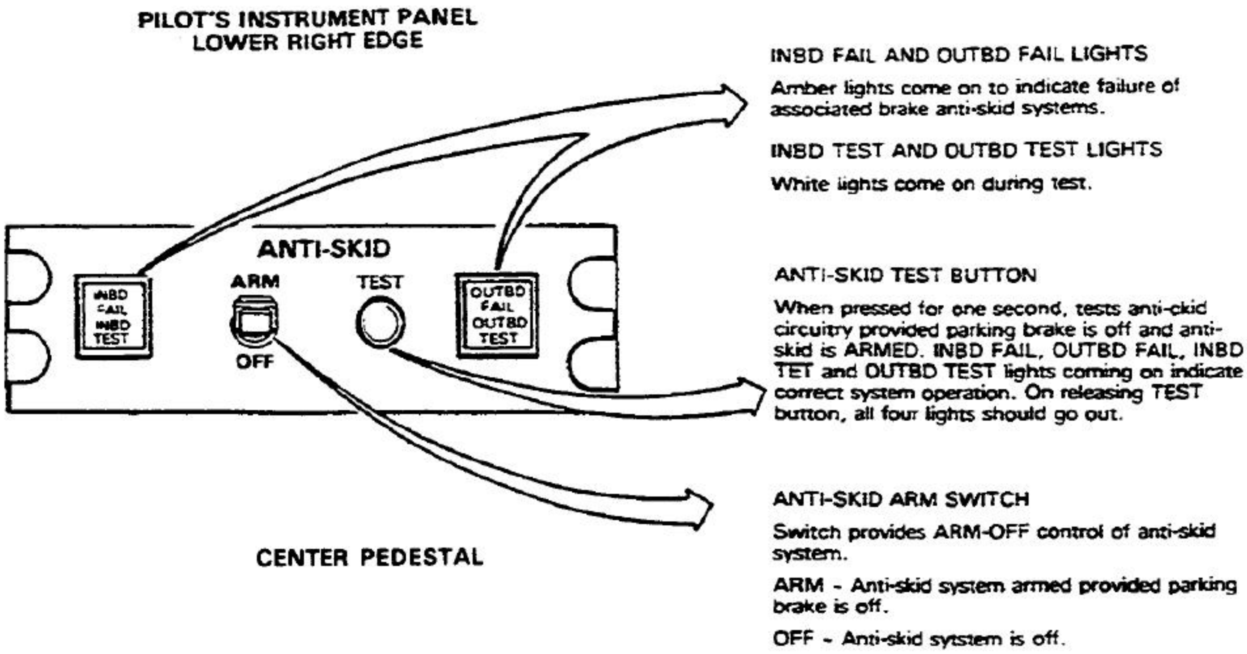

Figure 6. AMM illustration of the antiskid control panel in cockpit.

The following descriptions are cited from the AMM. The [bracketed text] has been added for clarity with respect to components involved in the accident investigation.

> The antiskid control system stops wheel skids, it is electrically activated through the arming switch installed on the landing−gear control panel. Each main wheel/tire assembly is connected to the wheel speed transducer which sends electrical signals to the antiskid control unit.[14] [See Figure 7] The antiskid control unit sends control signals to the dual antiskid control valve which increases or decreases the pressure of the hydraulic fluid which goes to the brake unit.
>
> The antiskid control system has the components that follow:
> – Four wheel speed transducers
> – One antiskid control unit
> – Two antiskid control valves
> – Four drive caps
> – Two antiskid relays.

[14] Note that some documents use the term transducer and others refer to the wheel speed sensor (WSS).

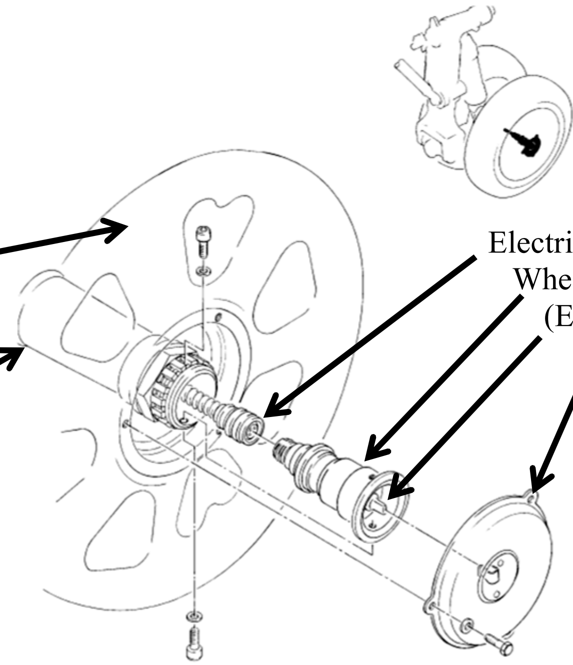

Figure 7. AMM illustration of the wheel speed transducer and drive cap components

> [Continued AMM description follows]
>
> One wheel speed transducer is installed in each end of the wheel axle of the main landing gear. The wheel speed transducers give sinusoidal signals to the antiskid control unit. The sinusoidal signals are directly in proportion to the rotational speed of each main wheel/tire assembly.
>
> The wheel speed transducer [is an electrical generator which] has a stator and a rotor. The stator is attached to the wheel axle, and the rotor is free to turn. The rotor is engaged with the drive cap of each main wheel/tire assembly [by means of a plastic coupling]. When the main wheel/tire assembly turns, it automatically turns the drive cap which [through the plastic coupling] turns the rotor around the stator. The rotation changes the magnetic field of the stator and makes a sinusoidal AC signal. This signal is transmitted through the electrical cables to the antiskid control unit.

The anti-skid control of each wheel is independent of the other three, while monitoring the other wheels for fault monitoring. In the air mode (as determined by proximity switches and the landing gear control unit (LGCU), the anti-skid control releases brake pressure. Upon landing, the anti-skid control ports hydraulic pressure away from the individual wheel brakes until the wheel velocity has reached 30 kts. At more than 30 kts, the anti-skid system control then checks for corresponding velocity from other wheels to initiate use of the wheel brakes and their anti-skid control. The anti-skid ceases to function when the wheels decelerate to 30 kts or less, or when a pilot de-activates the system with the on/off switch as an abnormal procedure.[15] (See Figure 6)

[15] The AMM contains additional detail about how the wheel speeds are referenced, landing protection, specific

The on-site testing found that the #3 and #4 wheel anti-skid systems functioned, as did the #2 WSS when installed into the #3 position. A fracture in the #1 anti-skid WSS plastic coupling was visible when the hubcap was removed by the IIC in Florida. The fracture was confirmed by the Systems Group Chairman at the NTSB Laboratory and submitted for examination of the fracture details, which are the subject of an attached report. (See Figures 8 and 8A) The #3 WSS was installed in the #1 position and the #1 system operated normally.

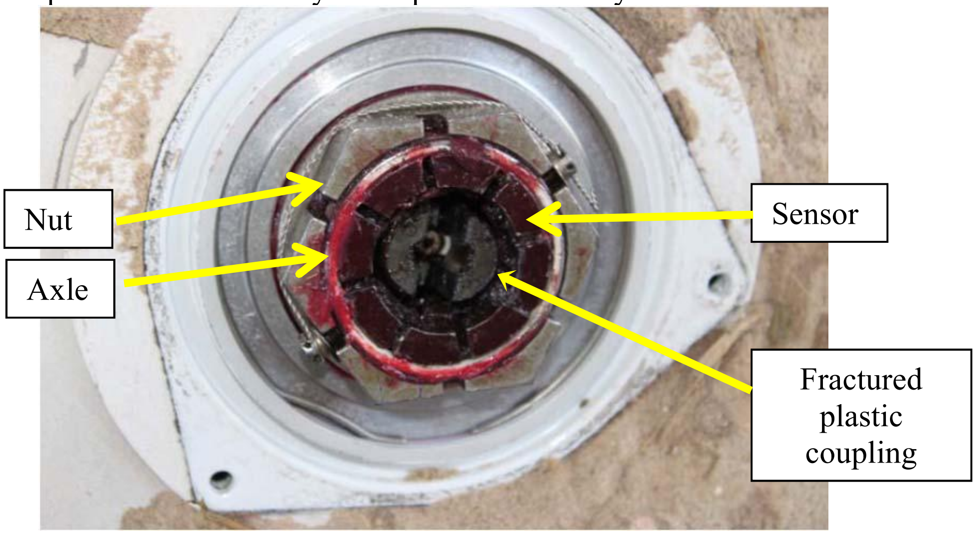

Figure 8. The #1 wheelspeed sensor (WSS) in axle, prior to removal, with visible break in plastic coupling. Photo provided by IIC.

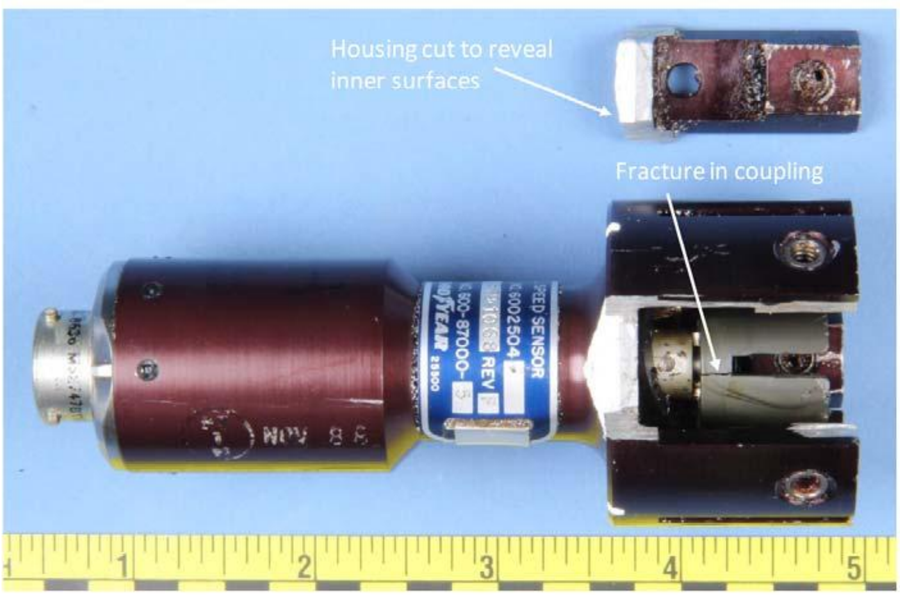

Figure 8A. Wheel speed sensor at NTSB Materials Laboratory after being cut by Systems Group Chairman, showing fracture in coupling.

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combinations of wheelspeed data to release the ground spoilers (27-60-00) and thrust reversers (78-30-00), as well as other details which are beyond those needed here.

Goodyear produced the WSS from 1979, and then sold this portion of the business to Meggitt. The data plate showed that the sensor had been manufactured by Goodyear, and the assembly number is 6002504, the Bombardier P/N is 600-87000-5, and the S/N is Aug 79-1068 Rev. F. The cannon plug pins were not damaged.

Small spiral-nails which had secured the plastic had backed out, allowing the coupler to rotate independently of the shaft. To remove the plastic coupling required cutting the end of the sensor. The plastic part was submitted to the NTSB Materials Laboratory for examination of the fracture and the body of the sensor was sent to the manufacturer for testing of the electrical portion with oversight delegated to the FAA. The #1 wheel speed sensor functioned after the manufacturer created a temporary adapter to take the place of the plastic coupling.

Meggitt was asked to search for service records regarding previous failures of the plastic coupling in the wheelspeed sensors with part number 6002504. The records since 2010 yielded 57 returns with no clevis (coupling) failures.

Following the extensive testing and examinations of the wheelspeed sensor, Bombardier Engineering personnel noted that loss of input from this sensor prior to landing would result in no activation of the brake for the #1 tire, due to the landing protection feature of the controller design. In a Bombardier email of July 12, 2016 was a statement that

> The loss of a wheel speed sensor output (or no data output, sheared shaft) is compared with the wheel pairs (i.e. 2 inboard and 2 outboard) and interpreted by the anti-skid controller logic as a deep skid. This will drive the associated anti-skid valve to a full pressure dump condition. Below 30 knots, the locked wheel circuit would be inhibited by the anti-skid controller logic and braking is restored to the wheel but no anti-skid protection.

In neither case would the tire provide braking, deceleration, or the flat spot which the tire had. In an email of December 15, 2016, Bombardier added the following:

> This is true when assuming a hard fail condition. If the fault was intermittent and the no. 1 wheel speed sensor exceeded 30 knots at one point on landing and then decreased below 30 knots, then the logic would have been satisfied to restore braking but no anti-skid. The coupler would have been spinning on the sensor shaft during landing. The aircraft was not equipped with an FDR and no checks were done in-situ at Marco Island to check if the speed sensor was intermittent because the check was considered potentially hazardous to personnel by the IIC. The #1 wheel speed sensor was tested at Meggit after the manufacturer created a temporary adapter to take the place of the plastic coupling.

LGCU, AIR/GROUND LOGIC, SPOILERS, THRUST REVERSERS:

After touchdown the Captain said that he tried to extend the ground spoilers but was unable, later indicating this may have been due to the complex process required. He reported the ground spoilers did not deploy, and when the nose landing gear contacted the runway, he applied the brakes and held the control yoke forward, but felt no deceleration. He indicated also trying to get the thrust reversers to deploy but indicated he did not think they deployed and he did not see any thrust reverser deploy lights. He indicated that each piggy back lever never unlocked; he could not get the levers into the reverse position.

The ground spoilers and thrust reversers are locked out by a combination of weight on wheels (WOW) detected from proximity sensors through the landing gear control unit (LGCU), and wheelspeed signals from the antiskid control unit installed in the main avionics compartment. This airplane was built prior to Service Bulletin (SB) 601-0113 and did not have auto deploy ground spoilers. In accordance with the Operating Manual,[16] the ground spoilers should deploy only if ALL the following conditions are met:

- The GROUND SPOILERS switch is in the ON position
- The spoiler control lever is moved up and rearward through the stop gate to the EXTEND position
- The left throttle lever is in the IDLE position or lower and
- A weight on wheels (WOW) or wheel spin-up signal is present

The ground spoilers and thrust reversers were tested by the IIC with Bombardier while on-site and found operational.

The LGCU was not tested as a complete unit. The function was noted through airplane performance and testing which included:

Actuation of anti-skid in wheels #1, #3, and #4 is inhibited in AIR mode. This required the LGCU to provide an "on ground" signal to the anti-skid controller during the accident landing.

The thrust reversers were checked in Ground Mode and the following was reported by the IIC, then confirmed by Bombardier:

> While the airplane was simulated being on the ground, one engine was operated at a time only to idle thrust, and with each thrust reverser armed, each thrust reverser solenoid on the throttle quadrant released and each thrust reverser was deployed three times followed by a slight increase in power. No discrepancies were noted with the thrust reversers. Safety concerns prevented full reverse thrust application.

[16] Publication ID PSP 601-6, Section 10, page 28

TIRES:

The on-site examination of the #1, #3, and #4 Goodyear tires documented flat spots through the tread, with the #1 tire missing the most material and a cross shaped tear through the inner-most plies, consistent with sudden depressurization. Addressing such flat spots, the Goodyear Aircraft Tire Care & Maintenance Manual states "This occurs when the tire stops rotating while the aircraft is still moving. The runway grinds off rubber and fabric as the tire is dragged along the surface." The Airplane Maintenance Manual (AMM) and tire care manuals from Michelin, and Dunlop have nearly identical photos and similar statements and example photos. (See Figures 9 through 11)

Note that the following three photos are not of tires from the accident airplane.

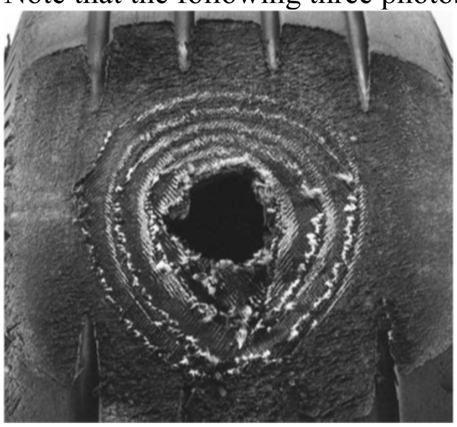


Figure 9. Photo of flat spot through tread of tire in Goodyear Aircraft Tire Care & Maintenance Manual. Caption states "Skid"

Figure 10. Photo of flat spot through tread of tire in Dunlop Care & Maintenance Manual. Caption states "Dry Braking Flats. Locked (or almost locked) wheels during a landing on a dry runway can cause a dry braking flat spot on a tyre. This is a flat scuffed surface on a part of the tread circumference."

Figure 11. Michelin photograph of flat spot on tire.

As tire #1 had the most significant flat spot, it was sent to the Group Chairman for examination. Detailed photographs were taken and electronically shared with group members for telephone discussion.

The following markings were on the #1 tire:

Goodyear Flight Leader
25.75 x 6.75 – 14
Part Number 256K43-3, 210 MPH
Serial Number 33097507, N06-2, 14 Ply Rating
Load Rating 10300 LBS
RUA DO PRAZERES 284 [illegible]TRIA
BRASILEIRA ESTADO DE SAO PAULO
TSO-62d, BS0612 – AR – 483MR
.30 in / 7.6mm SKID

The #1 (outboard left) main landing gear tire strongly resembled the Michelin example with a flat spot through the tread and casing of the tire which had an X-shaped tear through the plies at the center which had not been ground away. (Figures 11 through 13) The tear was consistent with rupture of the inner bladder by release of pressure. Detailed examination of the #1 tire revealed no evidence of operation at low pressure, pre-existing damage, or of manufacturing defects. The tire also had a tear/cut to a hole at the edge of the flat-spotted area.

Figure 12. Oblique view of flat spot on Tire #1, showing serialized shoulder. Note numbering added for

Figure 13. #1 tire on wheel, as recovered. Photo provided by Investigator in Charge.

examination references.

The examination of tire #1 found no blue tinted rubber or reverted rubber on the interior, exterior, or in the bead areas. No evidence of bead movement or damage was found. The interior liner had no evidence of low pressure operation or operating with sidewall collapse, such as flexure marks around the circumference (localized flex marks are described later), cuts, pinches, or sidewall polishing.

The flat spotted and torn areas revealed the internal construction of the tire. No design or construction anomalies were noted in these areas. The plies were straight and parallel in each orientation. No loss of adhesion was found between the plies or between the tread construction and loss of tread. Torn small fragments of rubber remained in the fabric plies where the tread had separated. No evidence of repair-related damage was found.

The interior surface of the tire had a 3 ounce manufacturing balance patch of 8.75 inch length, located across the periphery from the flat spot.

The X-patterned tear through the flat area was used as the 12 o'clock orientation to mark the tire sidewalls and tread. The orientations include a lower-case "s" on the sidewall marked with the serial number. For example, "12s" was marked on the serialized sidewall at the center of the flat spot and "12" was marked on the non-serialized sidewall. As mounted on the airplane, the serialized sidewall had been oriented outboard and to the left, away from the airplane so that the serialized numbers would contact the ground in order as the airplane rolled forward. (1s, then 2s, then 3s, etc.) (See Figures 12, 14, and 15)

Figure 14. Tire with markings and scale in inches at NTSB laboratory.

The tread was evenly worn outside of the area with the flat spot. The depth of the tread grooves was measured at each orientation around the periphery with the following results:

1: 0 – 0.028”
2: 0.100” – 0.102”
3: 0.132” – 0.148”
4: 0.114” – 0.144”
5: 0.136” – 0.141”
6: 0.132” – 0.145”
7: 0.123” – 0.139”
8: 0.163” – 0.171”
9: 0.175” – 0.179”
10: 0.151” – 0.164”
11: 0.123” – 0.134”
12: The bladder and a single ply remained with a total thickness of 0.124”

Over a length of 11.5 inches, from 11 o’clock to 1 o’clock, the tread was worn through in the flat spot, exposing the inner liner. The serialized sidewall folded under the tread and the sidewall had chafed through near the marking 1s, extending to the mark 2s. (See Figure 15) Minor sidewall folding flexure marks were found limited to the portion of the sidewalls centered on the X-shaped damage, from about 3 to 8 o’clock. Grass was found caught in the sidewall tears at the markings 1 and 11s.

Figure 15. Direct photo of flat spot centered on tread. The 1 o’clock orientation is at top.

A sharp-edged circular hole of about slightly more than quarter-inch diameter was found at the end of the X-shape nearest near the 11 o'clock marking. The wheel flange was subsequently found to have about the same lateral distance from center, straightness of cut/tear toward X-shaped damage, parallel nature of the cut/tear with the wheel flange, and approximate diameter of the hole. (See Figures 16 and 17)

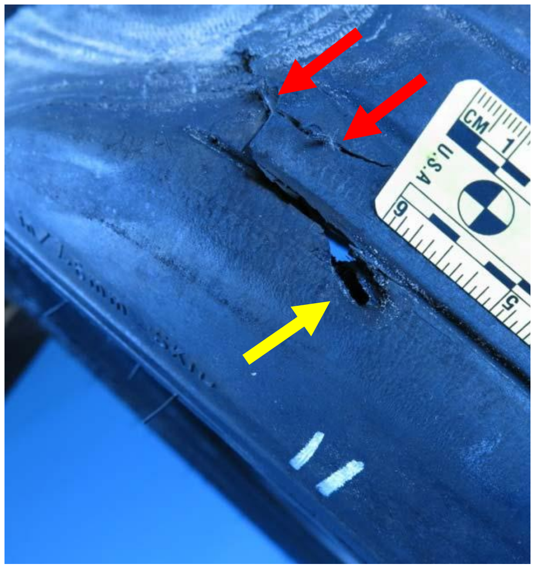


Figure 16. Hole in tread. (See yellow arrow from left) Material displaced outward is above the hole. (See red arrows from right) As installed, the tire would roll toward the camera.

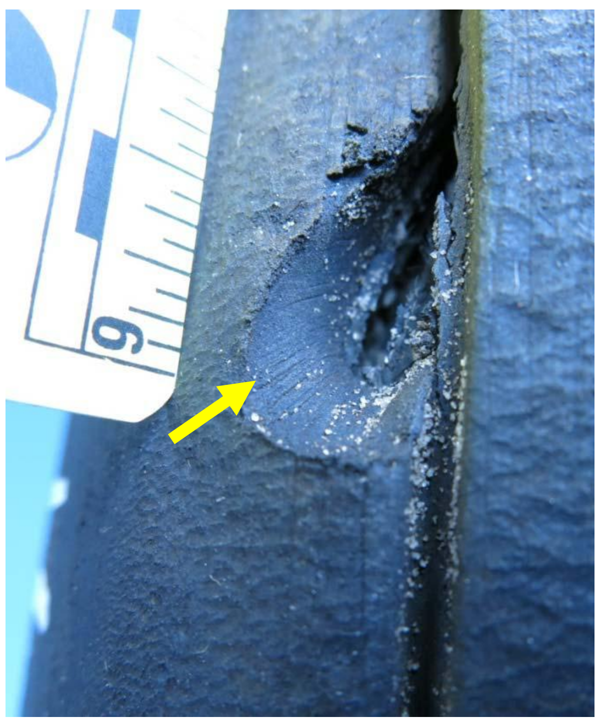


Figure 17. Detail of hole, showing striations. (arrow)

The circular portion of rubber was missing at this location aligned on the interior of the tire with a missing conical portion of material. At the center, the plies were displaced inward and covered by a tongue of bladder material. The interior of the tire had a straight tear or cut from the hole to the end of the X-shaped tear. (See Figures1 8 and 19)

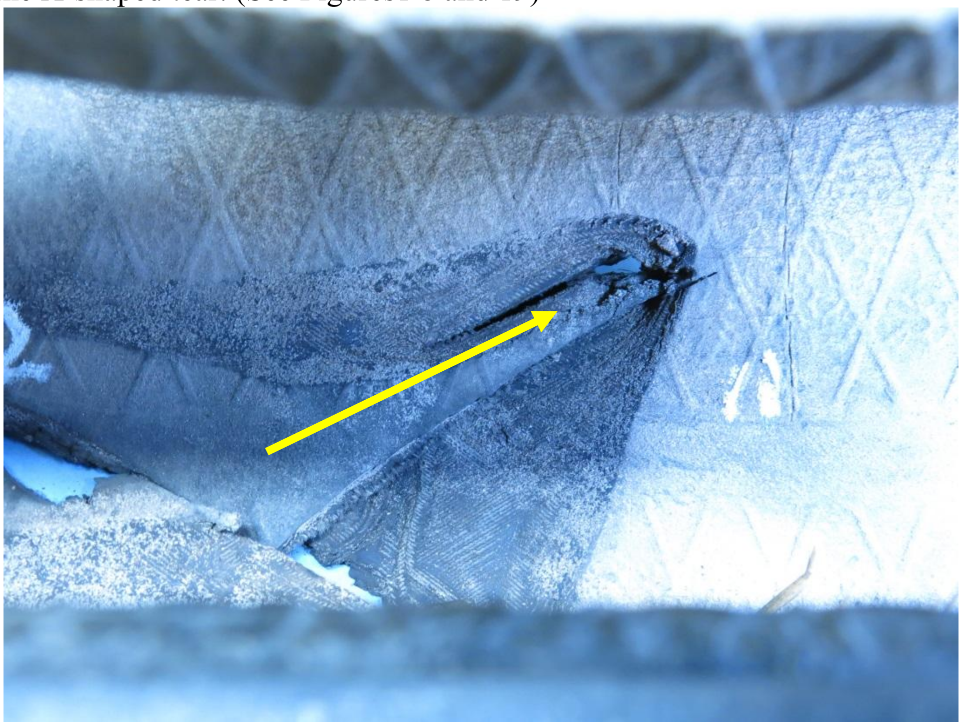


Figure 18. Interior of tire at hole, showing conical loss of plies radiating out from the hole and straightness of cut/tear toward X-shaped damage. The tongue of liner material overlays the missing material from the lower left, and inward ply damage is visible at the tip of the tongue. (The yellow arrow is oriented on tongue from base toward tip and points at the inward ply damage.)

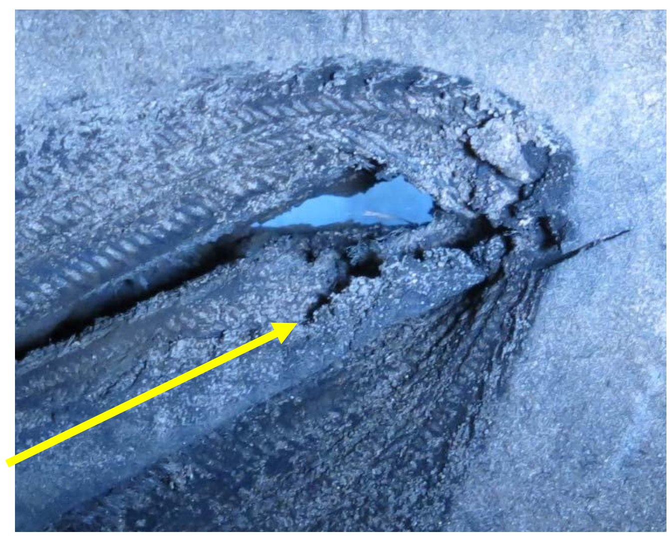


Figure 19. Detail of damage at tip of tongue in Figure 7. Note inward tear of flap at tip of arrow on tongue.

TIRE EXAMINATION, TIRE 2

The #2 tire was found within inflation pressure limits and had tread remaining.[17] It had cuts and other damage consistent with operation off of the paved runway surface and did not have the flat spots through the tread found in the other three tires.

Figure 20. The tread of the #2 main landing gear tire. (Image brightness increased for visibility)

Figure 21. Sidewall of the #2 main landing gear tire. (Image brightness increased for visibility)

[17] Photographs of Tire #2 (See Figures 20 and 21) were provided by the IIC

FAA SAFETY RECOMMENDATIONS

The FAA has an internal procedure for initiation of safety-related changes, known as safety recommendations. An FAA Memorandum of June 30, 2015, contained five safety recommendation proposals[18] and an FAA Memorandum of August 26, 2016, contained the following three safety recommendations:[19]

15.092 Issue an Airworthiness Directive for Bombardier CS600/601 aircraft, CRJ aircraft and users of Tactair Brake Control Valve P/N: HP1333100-9, Bombardier P/N: 600-75115-9 CL-600-601. On all Brake Control Valves installed or re-manufactured prior to September 1990, inspect the Brake Control Valve at next major inspection for suspect power brake springs (having only one dead coil). Replace with new Power Brake Spring with three dead coils.

15.093 Issue a Special Airworthiness Information Bulletin (SAIB) to alert Principal Inspectors and owners/operators of the above concern.

15.094 Bombardier should issue a Mandatory Service Bulletin and letter to CL600/601 CRJ aircraft owners to alert them to the above concern.

The Memorandum states that the TCCA is the primary regulatory agency and will not address these until release of the final NTSB report.

Robert Swaim
National Resource Specialist
Aircraft Systems Engineering

[18] See Attachments for copies of the FAA Memorandums.

[19] From John Stuber and James Wilborn of the Safety Management Branch, ANM-117, to Angela Anderson, Manager, Management Services and Recommendations Division, AVP-100.

ATTACHMENTS

NTSB Materials Laboratory Factual Report 15-048

Meggitt report

An FAA Inspector Statement from participation at Meggitt is attached.

FAA Memorandum dated 6/30/2015 from Robert Lacourse to Angela Anderson, containing five potential safety recommendations.

Note #1. An image which is blurred was received as shown.
#2. A referenced report from Tactair was placed in the docket previously and is not attached.

FAA Memorandum dated August 26, 2016 from John Stuber to Angela Anderson, containing three FAA internal safety recommendations.

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

June 26, 2015

MATERIALS LABORATORY FACTUAL REPORT Report No. 15-048

A. ACCIDENT INFORMATION

Place	:	Marco Island, Florida
Date	:	March 1, 2015
Vehicle	:	Canadair CL-600 Challenger
NTSB No.	:	ERA15LA140
Investigator	:	Robert Swaim

B. COMPONENTS EXAMINED

Fractured pieces of a coupling from a Goodyear model 6002504 wheel speed transmitter.

C. DETAILS OF THE EXAMINATION

Images of the wheel speed sensor are shown in Figures 1 and 2 with the fractured coupling in place. Visual evaluation of the coupling pieces revealed that the coupling was injection molded from polymer with the injection gate on the external cylindrical wall and the ejection pin locations on the top (as indicated in Figure 2). The fractured coupling is shown in Figure 3.

Closer views of the fracture surfaces of the coupling are shown in Figure 4. The hackle and rib markings[1] on the fracture surfaces are consistent with overstress fracture. As shown in Figure 4a, there is a shrinkage void on the fracture surface. The fracture initiated in bending overstress at the corner and re-initiated at the void as indicated in the figure. Similarly, the fracture initiated in bending overstress at the corner in Figure 4b. In the fracture initiation regions, the corners exhibited very small filet radii.

Fourier transform infrared spectroscopy revealed that the coupling is fabricated from unfilled polycaprolactam (polyamide 6).

Michael Budinski
Chief, Materials Laboratory

[1] M. D. Hayes, et. al. Fractography in Failure Analysis of Polymers, Elsevier, United States, 2015, pp.70-75.

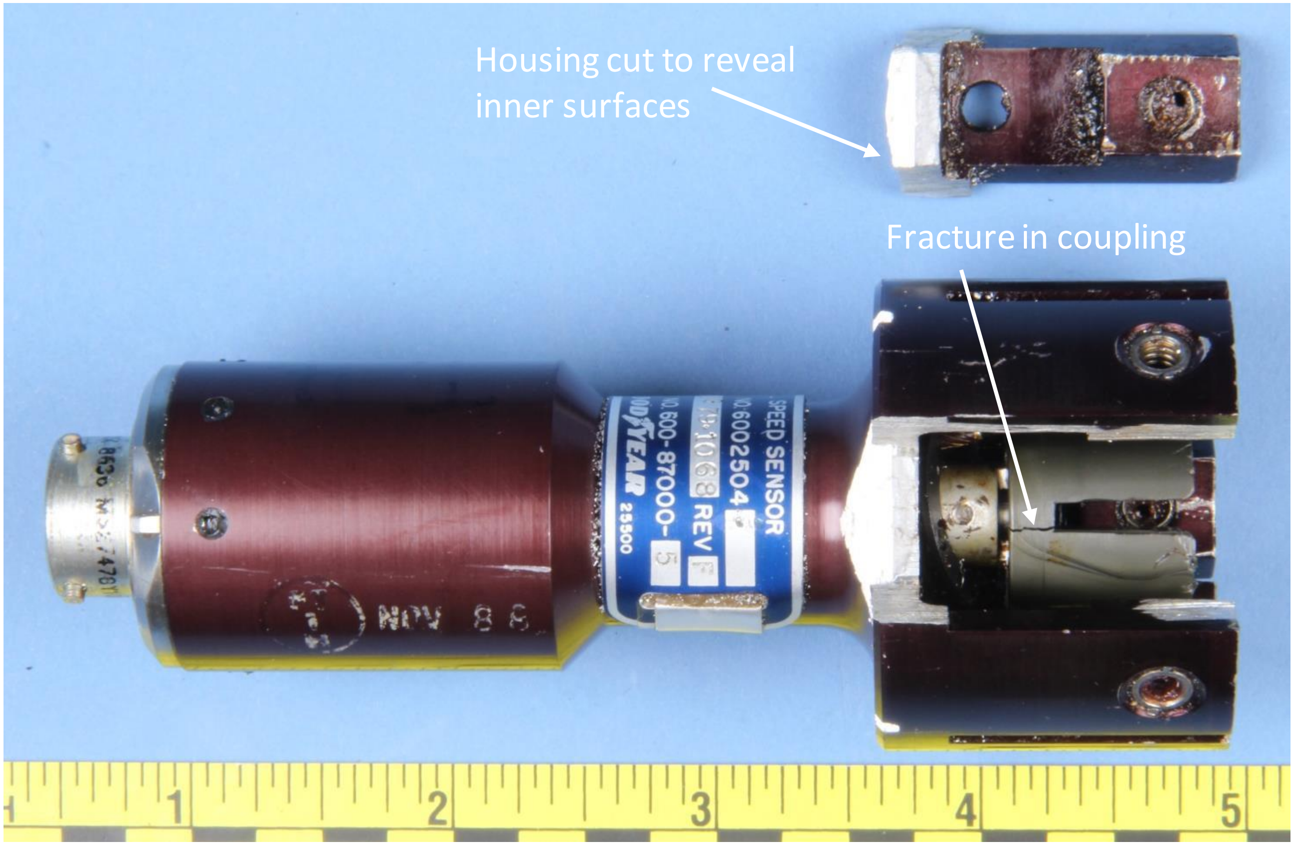


Figure 1 Side view of the wheel speed transmitter. A portion of the housing was removed to reveal the coupling. A fracture in the coupling is identified.

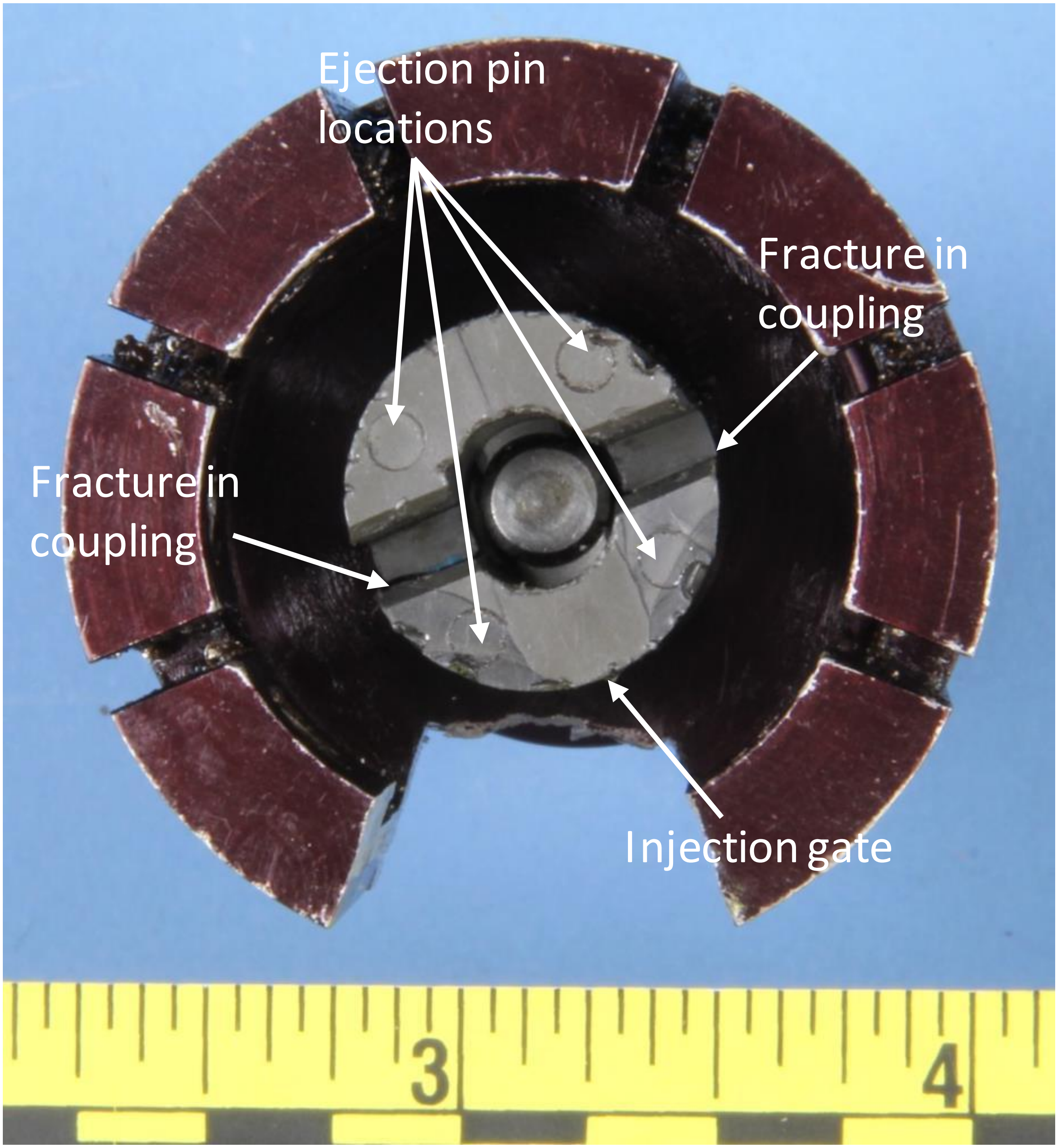


Figure 2 Top view of the wheel speed transmitter showing the fractured coupling in place. The fractures are identified as well as the location of the injection molding gate and the ejection pin locations.

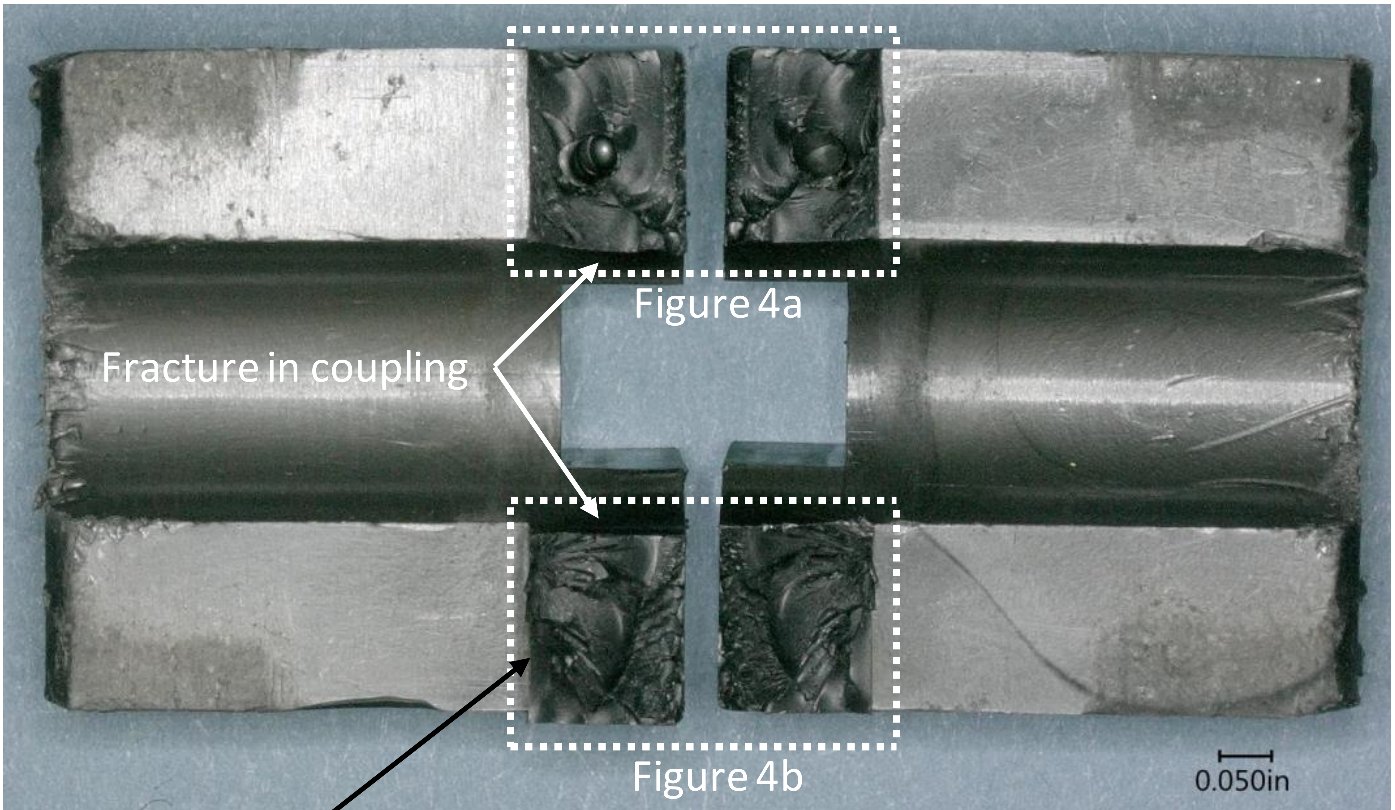


Figure 3 Image showing the two halves of the fractured coupling. Closer views of the fractures surfaces are depicted in Figure 4.

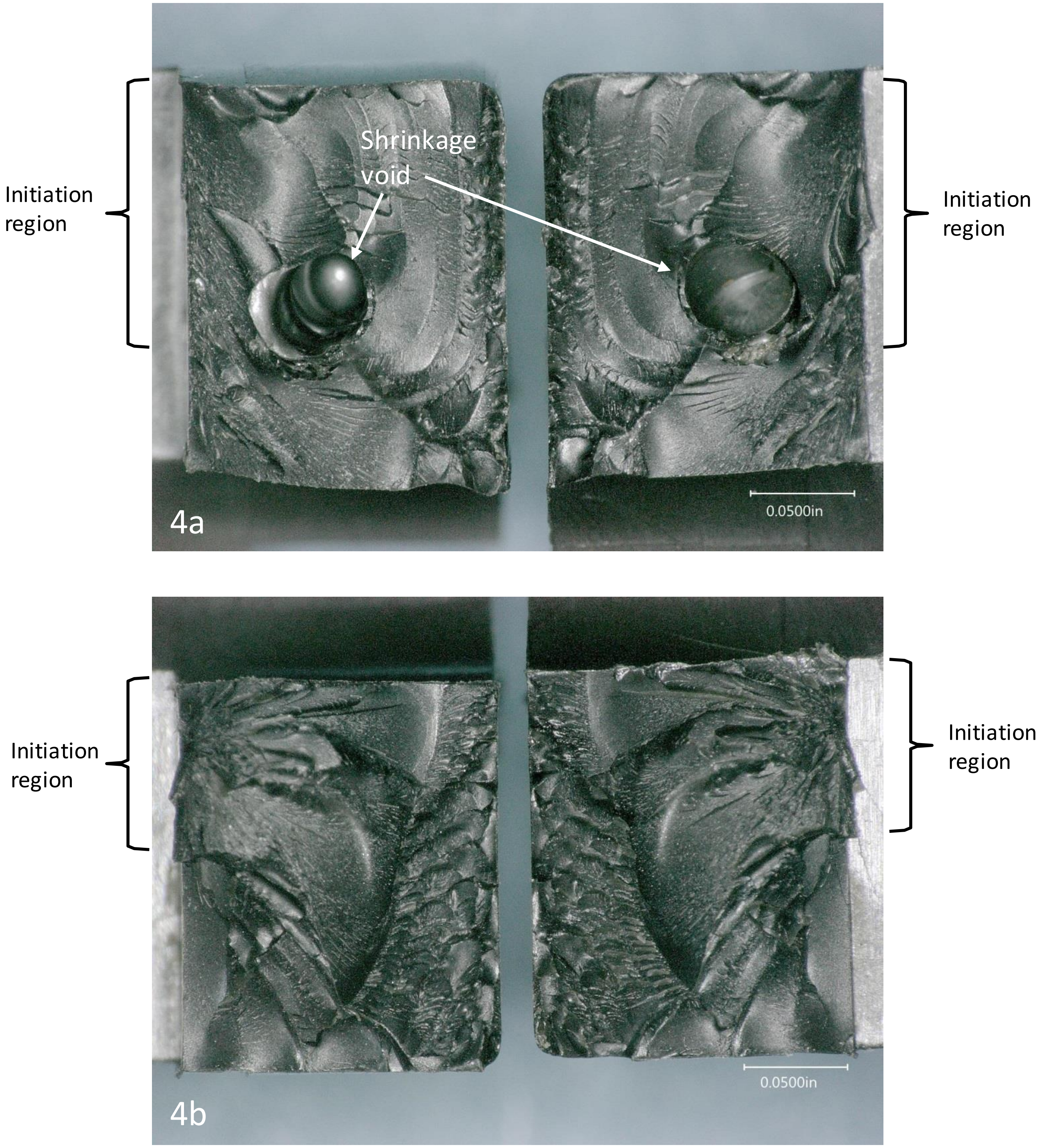


Figure 4 Closer views of the fracture surfaces on the coupling in Figure 3.

Ref: NTSB ID# ERA15LA140

7/2/2015

Meggitt ABSC Test Lab - Akron, Ohio

Meggitt Representatives

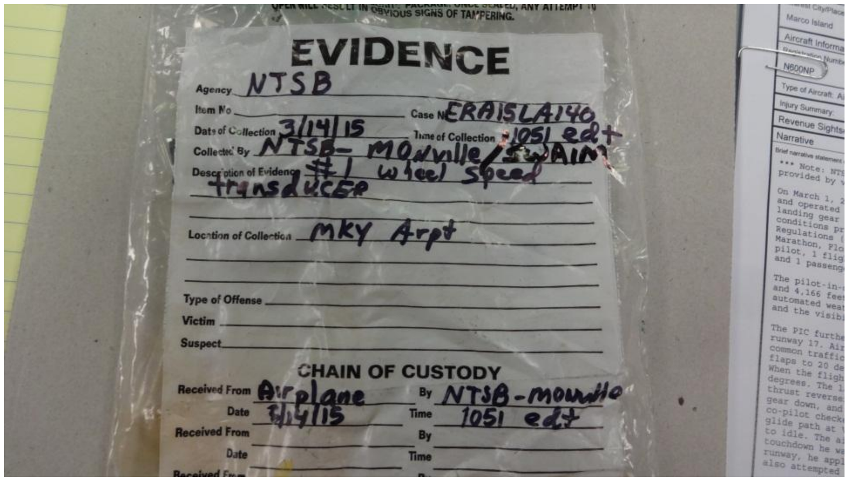
- David Yusufi ________________________
- Bill Ward ________________________
- Kristen Carpino ________________________

FAA Representative

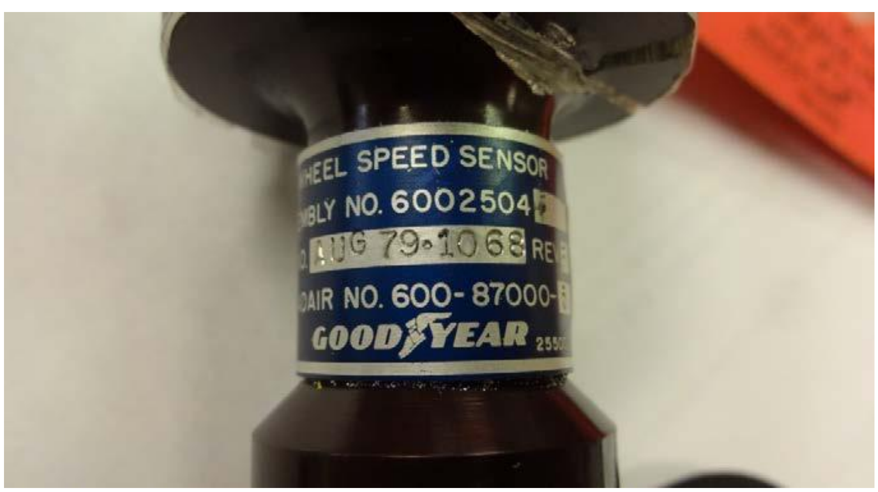
- Kenneth Shauman ________________________

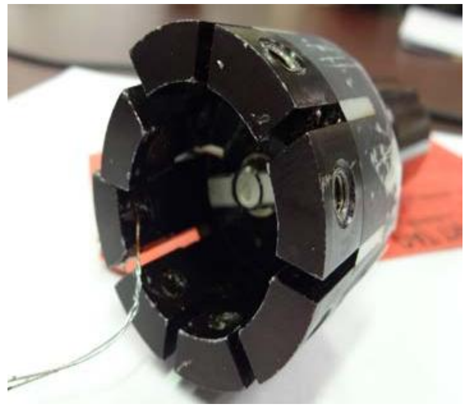
An aircraft was involved in a landing overrun incident. Meggitt Aircraft Braking Systems has been asked to evaluate Brake #3, Brake #4 and a wheel speed transducer (WST) from the aircraft. The two brakes were sent to MABS in sealed boxes and were received June 16th, 2015. Both brakes were moved to the Test Lab and remained closed awaiting inspection.

The wheel speed transducer was hand carried to MABS by the FAA.



On Thursday, June 25th 2015, Meggitt Aircraft Braking Systems performed an examination on these three items under the supervision of the FAA. Bill Ward, David Yusufi, Kristen Carpino and Ricardo DeMartini led the examination for MABS and Ken Shauman was present to witness on behalf of the FAA. At approximately 10:00 am, all parties gathered in a conference room and discussed the preliminary report and reviewed the agenda for the day. Ricardo DeMartini was brought in from Systems Engineering to set up the test rig for the wheel speed transducer. The unit was photographed, documented and then passed off to Systems to get started with setup and testing. A special setup was needed since the coupler was missing. A section of the WST housing in the coupler area was cut away and taped back into place prior to MABS examination.





The remainder of the team went down to the test lab to begin the brake examination.

Brake assembly 5009027-5 s/n MAY82-418

The box containing Brake #3 was opened by the FAA.

A visual inspection of the brake assembly took place. Serial Number MAY82-814 had considerable damage to the water shield and at one port of the housing. The housing was damaged enough to not allow the brake to be pressurized to validate function.

Notes from the brake exam:

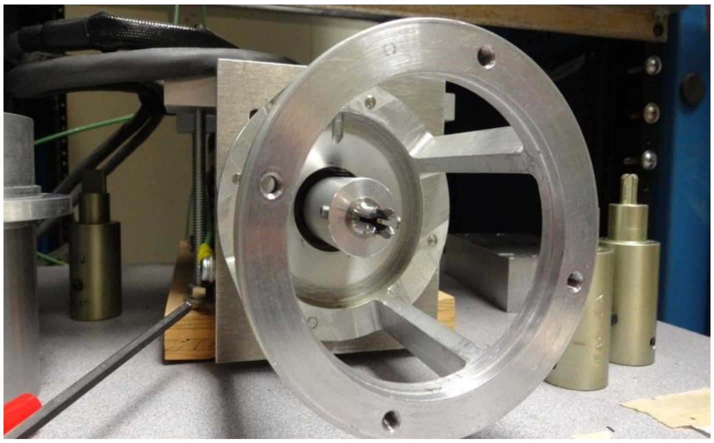
- Housing identification markings are consistent with MABS drawings
  - “ASSY 5009027-5”
  - “SERIAL MAY82-418”
  - “SUBASSY 5006194”
  - “PART 5006193”
  - “FORG 5006192 P1”
  - “600-85123-91”
- Backplate and bolt heads identification markings are consistent with MABS drawings
  - Backplate “PART 5006260”, “LOT 14”
  - All six (6) bolt heads “GYS206-81W” and “z” (supplier marking)
  - All six (6) bolt heads are properly engaged with the backplate
- Rotor subassembly identification markings are consistent with MABS drawings
  - Rotor 1 and 3 “5013450”
  - Rotor 2 “5013456”

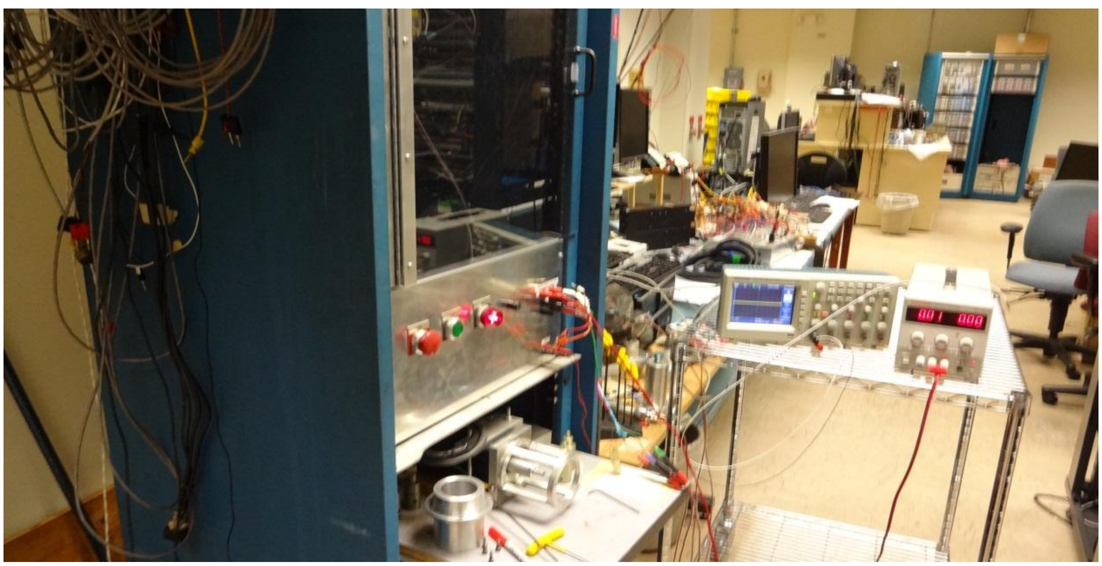
- Pressure plate, stators and endplate subassembly identification markings were not verified since they are located on the inside diameter channels, which are only readable after brake disassembly.
- Carbon disk serial numbers were difficult to read with the brake assembled. Some serial numbers were recorded. If needed, serial numbers could be verified after brake disassembly.
- It was agreed not to disassemble the brake at this time.
- Lockwire observations
    - No lockwire on bleeder hardware
    - Lockwire intact on all five cylinder sleeves
    - Lockwire intact at unused (plugged) inlet port
    - Housing is significantly damaged at unused (plugged) bleeder port making it impossible to determine if lockwire was in place
- By visual inspection, the housing damage at the unused (plugged) bleeder port was deep enough to compromise the sealing surface of the machined port such that the brake would not hold pressure even if the damaged plug/seal were replaced.
- Wear pin is intact and properly attached to pressure plate. Wear pin measurement is 0.320 – 0.325" without any hydraulic pressure applied.
- The overall condition of the carbon stack was good
    - All visible channels (rotors and stators) were intact
    - No signs of carbon damage
    - No signs of carbon oxidation (based on firmness of carbon)
- There are no signs of the brake being exposed to high temperatures based on the condition of the carbon disks' coating and channels, and the brake housing color.
- The brake water shield and housing are damaged at the bottom of the brake, directly opposite the bleeder port (i.e. top of the brake). Apparent ground debris/vegetation is trapped in the general area of the damaged shield and housing. Some of the housing paint has peeled off the housing in this same general area. The remaining portion of the damaged plug was removed from the damaged port. Visual examination verified the absence of the sealing surface.
- Other than the previously mentioned damage, the condition of the brake looks normal for field return
    - Torque Tube surface corrosion is considered normal
    - Axle attachment location indicates fasteners were in place
    - Tie bolt nuts are intact and could not be loosened by hand
    - Bleeder and inlet fitting hardware is intact and could not be loosened by hand
    - All carbon disks move freely (rotors rotate; stators do not rotate but slide freely on torque tube.
    - There is clearance between each piston insulator and the pressure plate (unpressurized brake)
    - The pistons, insulators, cylinder sleeves all look intact with no visual indications of misalignment
    - Brake water shield orientation is correct

Upon completion of the exam, the #3 brake assembly was placed back in the box. The remains of the removed plug was bagged and placed in the box. The box was then sealed at the end of the examination.

WST assembly 6002504 s/n AUG79-1068

Upon completion of Brake #3, the team went up to the Systems Test Lab to witness the functional check of Wheel Speed Transducer #1. The transducer was connected to the test rig and varying speeds were applied through an external power supply.

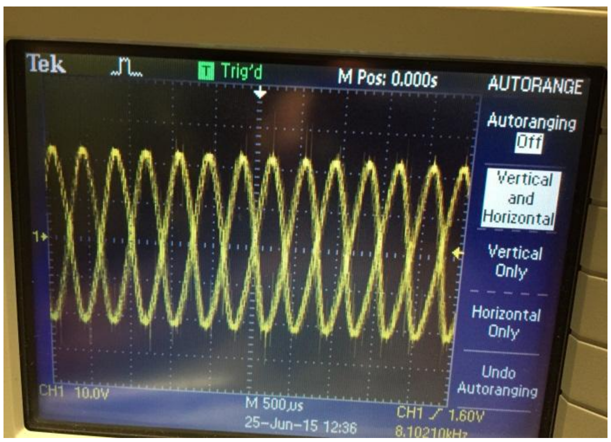


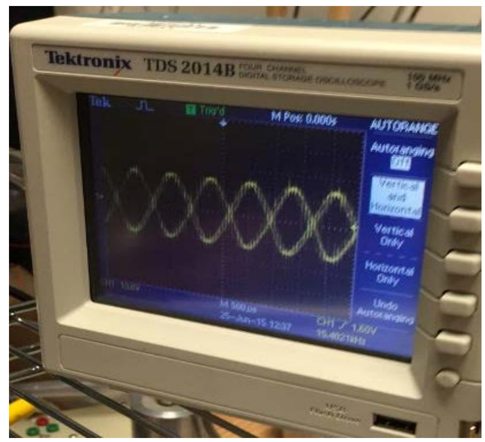


Notes from the WST exam:

- Housing identification markings are consistent with MABS drawings
  - "ASSY 6002504"
  - "SERIAL MAY82-418"
  - "REV F"
  - "600-87000-5"
- Coupler was missing from the WST and thus not a part of this exam.

- Housing was partially sectioned off prior to MABS exam.
- Drive screws: (1) drive screw was taped to the part tag. (2) drive screws were present in the assembly. (1) drive screw was missing. These drive screws are the means of attaching the coupler.
- A consistent sinusoidal wave was achieved.





Brake assembly 5009027-5 s/n OCT81-84

The box containing Brake #4 was opened by the FAA.

A similar visual inspection of brake #4 took place. Serial Number OCT81-84 showed similar damage to that of brake #3. Again, there was considerable damage to the water shield and at one housing port location. The housing was damaged enough to not allow the brake to be pressurized.




Notes from the brake exam:

- Housing identification markings are consistent with MABS drawings
    - "ASSY 5009027-5"
    - "SERIAL OCT81-84"
    - "SUBASSY 5006194"
    - "PART 5006193"
    - "FORG 5006192"
    - "600-85123-91"
- Backplate and bolt heads identification markings are consistent with MABS drawings
    - Backplate "PART 5006260", "LOT 5"(or 6?)
    - Five (5) bolt heads "GYS206-81W" and "z" (supplier marking)
    - One (1) bolt head has dot matrix identification "GYS206-81W" and "SPS 03" (supplier marking)
    - All six (6) bolt heads are properly engaged with the backplate
- Rotor subassembly identification markings are consistent with MABS drawings
    - Rotor 1 and 3 "5013450"
    - Rotor 2 "5013456"
- Pressure plate, stators and endplate subassembly identification markings were not verified since they are located on the inside diameter channels, which are only readable after brake disassembly.

- Carbon disk serial numbers were difficult to read with the brake assembled. If needed, serial numbers could be verified after brake disassembly.
- It was agreed not to disassemble the brake at this time
- Lockwire observations
    - No lockwire on bleeder hardware
    - Lockwire intact on all five cylinder sleeves
    - Lockwire at inlet fitting is broken
    - Lockwire intact at unused (plugged) inlet port
    - Housing is significantly damaged at unused (plugged) bleeder port. Broken lockwire was observed but the degree of housing damage made it impossible to determine if lockwire was properly attached.
- By visual examination, the housing damage at the unused (plugged) bleeder port was deep enough to compromise the sealing surface of the machined port such that the brake would not hold pressure even if the damaged plug/seal were replaced.
- Wear pin is intact and properly attached to pressure plate. Wear pin measurement is 0.330-0.340" without any hydraulic pressure applied.
- The overall condition of the carbon stack was good
    - All visible channels (rotors and stators) were intact
    - No signs of carbon damage
    - No signs of carbon oxidation (based on firmness of carbon)
    - A white substance was observed, mainly on the outside diameter of rotor #3, less than ½ the circumference around the disk. Lesser amounts of white substance were noted on the endplate and stator #2 outside diameter, less than ¼ the circumference around the disks. White substance was not visible on the friction surfaces of the disks.
- There are no signs of the brake being exposed to high temperatures based on the condition of the carbon disks' coating and channels, and the brake housing color.
- The brake water shield and housing are damaged at the bottom of the brake, directly opposite the bleeder port (i.e. top of the brake). Apparent ground debris/vegetation is trapped in the general area of the damaged shield and housing.
- Other than the previously mentioned damage, the condition of the brake looks normal for field return
    - Torque Tube surface corrosion is considered normal
    - Axle attachment location indicates fasteners were in place
    - Tie bolt nuts are intact and could not be loosened by hand
    - Bleeder and inlet fitting hardware is intact and could not be loosened by hand
    - All carbon disks move freely (rotors rotate; stators do not rotate but slide freely on torque tube.
    - There is clearance between each piston insulator and the pressure plate (unpressurized brake)
    - The pistons, insulators, cylinder sleeves all look intact with no visual indications of misalignment
    - Brake water shield orientation is correct

Upon completion of the exam, the #4 brake assembly was placed back in the box. The box was then sealed at the end of the examination.

A debrief took place after the completion of brake #4. A review of all three units was discussed by the team and all notes were gathered. The team attempted to contact the NTSB for further direction, but was unsuccessful. It was agreed by all parties to submit a draft report of the findings to Kenneth Shauman by the July 3, 2015 for review. MABS QA directed the MABS team members to quarantine the brakes. The two brakes were sealed in the original boxes and quarantined. The wheel speed transducer was placed back in the original bag and given to Kenneth Shauman of the FAA. All digital media generated during the exam will be available upon request.

U.S. Department
of Transportation
**Federal Aviation
Administration**

Flight Standards
Great Northern Tech Park II.
25249 Country Club Blvd.
North Olmsted, Ohio 44070

July 07, 2015

Mr. Timothy W. Monville, Sr. Air Safety Investigator
NTSB
45065 Riverside Parkway
Ashburn, VA 20147

Dear Mr. Montville:

Upon an earlier request for FAA assistance and participation in the accident investigation, NTSB Investigation Number ERA15LA140, I visited Meggitt Aircraft Braking Systems Corporation Production Test Lab, 1204 Massillon Road, Akron, OH, on June 25, 2015.

At the Meggitt facility were the accident aircraft's #3 and #4 brake assemblies. I hand carried the #1 Wheel Speed Transducer that had been previously direct shipped to the Cleveland Flight Standards District Office.

I was present and observed the examination of the brake assemblies and wheel speed transducer testing.

I have read the July 02, 2015, Meggitt Report. I concur with the descriptive observations and testing results for the #3 and #4 brake assemblies and wheel speed transducer contained in that report.

Sincerely,

[redacted]

Ken Shauman
Principal Maintenance Inspector

Federal Aviation Administration

Memorandum

Date:	6/30/2015
To:	Angela Anderson, Manager, Management Services and Recommendations Division, AVP-400
From:	EA23 - FSDO
Prepared by:	Robert Lacourse, ASI
Subject:	Federal Aviation Administration (FAA) Safety Recommendation

Background:

NTSB Case # ERA15LA140 occurred on March 1, 2015, where a Bombardier CL-600-2A12, N600NP, operated by Six Hundred NP, LLC, experienced a landing over-run and subsequent collapse of the nose landing gear at the Marco Island Airport (MKY), Marco Island, Florida. It was reported that upon landing, the pilot was unable to extend the ground spoilers. He then applied "moderate" braking, but felt no deceleration. He also attempted to deploy thrust reversers, but was unable. The pilot informed the co-pilot that there was no braking energy and released the brakes; the anti-skid was turned-off and the brakes were re-applied hard. He did not feel any deceleration. He began to modulate the brakes, but was unable to stop. Right rudder input was added, causing the aircraft to veer to the right. The aircraft went off the runway into the sand causing the nose gear to collapse. Review of the maintenance records revealed the airplane was last inspected in accordance with a 800 hour inspection in accordance with the manfacturer's MSG3 program on January 14, 2015, at airplane total time of 15,737.0 hours and 9684 cycles. The airplane had accumulated 34.2 hours and 21 cycles since the inspection at the time of the accident.

Safety Concern:

Brake failure, loss of control of the aircraft. A failure condition was verified on the investigation unit which would result in lack of braking capability of the aircraft's left inboard brake. The root cause of this condition was determined to be a broken left power brake spring. The broken spring would cause the function of the power brake spring to fail, therefore, not transmitting load to the brake controller assembly, making the control valve inoperable.

Affected Aircraft/(Part):

Affected Aircraft: Bombardier CL-600-2A12, Bombardier Challenger 601

Affected Part: Brake Control Valve, Tactair P/N: HP1333100-9, Bombardier P/N: 600-75115-9 CL-600/601

Spring information

The P/N of the “new” spring design (with additional dead coils) is the same P/N as the broken spring discovered in the investigation unit. The design change to incorporate three (3) dead coils on each end of the spring was made by Hydra-Power at drawing Revision “D” (EDM 21439), in September of 1990. As stated, the change was controlled by revision to the spring drawing only with no part number change.

This office, in accordance with Order 8020-11C, Chapter 1, Paragraph 16, as authorized by U.S. Code 49, Public Law 103-272, Section 40101, makes the following recommendations:

#1 Recommendation: (Airworthiness Directive) Recommend an Airworthiness Directive for Bombardier CL600/601 aircraft and Bombardier CRJ aircraft and, or users of Tactair Brake Control Valve P/N: HP1333100-9, Bombardier P/N: 600-75115-9 CL-600/601. On all Brake Control Valves installed or re-manufactured prior to September 1990, inspect the Brake Control Valve at next major inspection for suspect power brake springs (having only one dead coil). Replace with new power brake spring with three dead coils.

Outcome results: Increased aviation safety, decreased accidents, increase to public safety.

#2 **Recommendation:** (Special Airworthiness Information Bulletin) The FAA should issue a Special Airworthiness Information Bulletin (SAIB) to alert Principal Inspectors and owners/operators of the above concern.

Outcome results: Increased overall aviation safety, by informing the owners/operators of the concerned area.

#3 **Recommendation:** Bombardier Aircraft Company should issue a Mandatory Service Bulletin and letter to CL600/601; CRJ aircraft owners to alert them of the above concern.

Outcome results: Increased overall aviation safety, by informing the owners/operators of the concerned area.

#4 **Recommendation:** Bombardier Aircraft Company should issue a change to their recommended inspection program to add the inspection of the brake control valve as a separate Phase inspection.

Outcome results: Increased overall aviation safety, by informing the owners/operators of the concerned area.

#5 **Recommendation:** The FAA should issue a Safety Alert (SAFO) to operators.

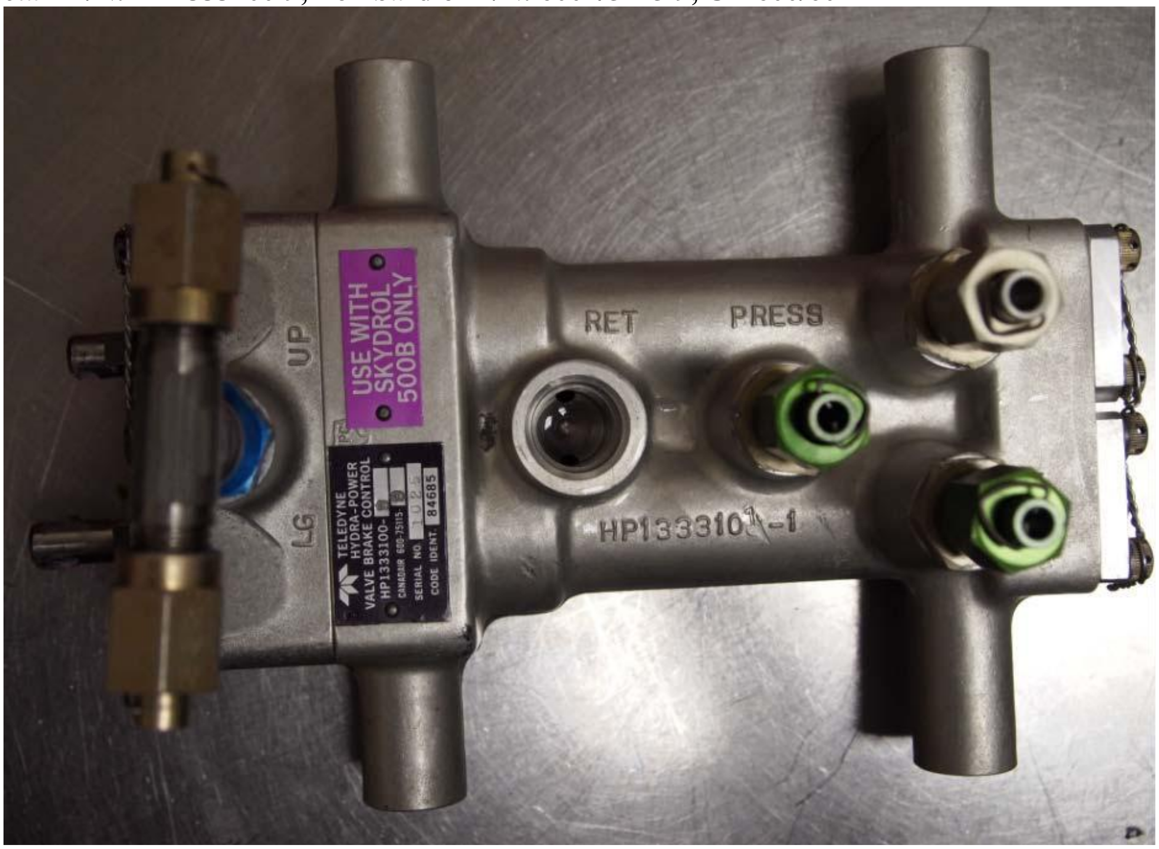
Outcome results: Increased overall aviation safety, by informing the owners/operators of the concerned area.

Robert L. Lacourse
ASI
(585) 436-3880 x218
EA-FSDO-23

Attachment(s): (4)

#1 Picture - Tactair Brake control valve, P/N: HP1333100-9, Bombardier P/N: 600-75115-9, CL-600/601
#2 Picture - Brake, power brake spring (Broken)
#3 Picture - Older design spring with one dead coil
#4 Picture - New Spring

#1 Tactair P/N: HP1333100-9, Bombardier P/N: 600-75115-9, CL-600/601



#2 Brake, power brake spring (Broken)

#3 Older design Spring with one dead coil

#4 New Spring

The P/N of the "new" spring design (with additional dead coils) is the same P/N as the broken spring discovered in the investigation unit.

Design change to incorporate three (3) dead coils on each end of the spring.

Made by Hydra-Power at drawing Revision "D" (EDM 21439), in September of 1990.

Change was controlled by revision to the spring drawing only with no part number change.

Federal Aviation Administration

Memorandum

Date: AUG 2 6 2016

To: Angela O. Anderson, Manager, Management Services and Recommendations Division, AVP-400

Thru: [redacted] ames Wilborn, Manager, Safety Management Branch, ANM-117 [redacted]

From: John Stuber, Safety Recommendations Program Manager, ANM-117

Prepared by: John Stuber, Safety Recommendations Program Manager, ANM-117

Subject: FAA Safety Recommendations 15.092 through 15.094

This is our follow-on response to FAA Safety Recommendations 15.092 through 15.094 regarding the Bombardier Challenger 601 Brake Control Valve.

The recommendations read as follows:

15.092 Issue an Airworthiness Directive for Bombardier CS600/601 aircraft, CRJ aircraft and users of Tactair Brake Control Valve P/N: HP1333100-9, Bombardier P/N: 600-75115-9 CL-600-601. On all Brake Control Valves installed or re-manufactured prior to September 1990, inspect the Brake Control Valve at next major inspection for suspect power brake springs (having only one dead coil). Replace with new Power Brake Spring with three dead coils.

15.093 Issue a Special Airworthiness Information Bulletin (SAIB) to alert Principal Inspectors and owners/operators of the above concern.

15.094 Bombardier should issue a Mandatory Service Bulletin and letter to CL600/601 CRJ aircraft owners to alert them to the above concern.

The accident that generated these safety recommendations is still under active investigation by the National Transportation Safety Board (NTSB). As such, Transport Canada Civil Aviation (TCCA), which is the primary regulatory agency, will not address these until the NTSB final report is released. We ask these recommendations be suspended, pending the release of the final NTSB report.

If you have any questions in reference to this matter, please contact Mr. Cesar Gomez, at 516-228-7318; or John Stuber, ANM-117, at 425-227-1129.