

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



ERA23FA235

SYSTEMS

Group Chair's Factual Report

April 9, 2025

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A. ACCIDENT

Location: Summerville, SC
Date: May 18, 2023
Time: 0018 EDT
0418 UTC
Airplane: HondaJet HA-420

B. SYSTEMS GROUP

Group Chair	Adam Huray NTSB Washington, DC
Group Member	Patrick Lusch FAA Washington, DC
Group Member	Thomas Sully Honda Aircraft Company Greensboro, NC

C. SUMMARY

On May 18, 2023, about 0018 eastern daylight time, a Honda Aircraft Company HA-420, N225HJ, was destroyed when it was involved in an accident at the Summerville Airport (DYB), Summerville, South Carolina. The commercial pilot and the five passengers were not injured. The airplane was being operated as a Title 14 *Code of Federal Regulations* Part 91 personal flight.

The airplane departed the Wilkes County Airport (UFK), North Wilkesboro, North Carolina, at 2329, on an instrument flight rules flight plan. The pilot and the passengers were returning to DYB where the airplane was based.

D. BRAKE SYSTEM DESCRIPTION

1.0 Master Cylinders

A master cylinder is a hydraulic actuator that pressurizes the brake system hydraulic fluid based on the input brake pedal command. When a master cylinder is not activated by the brake pedal, hydraulic fluid may pass freely between the master cylinder chambers. When activated, the inlet port is isolated from the downstream fluid cavity.

Four master cylinders are installed in the aircraft. Two are connected in series between pilot and co-pilot for the LH and RH braking.

2.0 Brake Shutoff Valve

The brake shutoff valve removes brake pressure to the power brake and antiskid valve when landing gear up pressure is applied. The brake shutoff valve minimizes internal hydraulic system fluid leakage during flight and thus reduces the cycle rate of the hydraulic pump.

3.0 Power Brake and Antiskid Valve

The power brake and antiskid valve is an electro-hydro-mechanical device that provides pressure to the brakes. The power brake and antiskid valve supplies pressure to the brake port when a command pressure is provided from the master cylinders. Brake pressure is proportional to the input master cylinder pressure.

The antiskid control valve within the power brake and antiskid valve uses an antiskid current signal from the digital antiskid control unit to drive a servo valve to relieve brake pressure. The magnitude of the brake pressure relief is proportional to the magnitude of the antiskid current signal.

One power brake and antiskid valve is installed in the aircraft in the fairing.

4.0 Brake Assembly

The main landing gear brake assembly is a multiple-disc brake that utilizes four rotating steel discs and three stationary steel discs. The installation is interchangeable between the left and right axle provided the orientation of the shuttle valve is rotated 180 degrees prior to swapping. The brake assembly comprises a cylinder housing containing four piston assemblies, shuttle valve, two bleed ports, two visible wear indicators, four adjuster assemblies, back-plate, torque tube, pressure plate, four rotating discs, and three stationary discs. The rotor assemblies are between the pressure plate, stationary disk, and back-plate assemblies.

The cylinder housing torque pin mounts on the trailing arm to hold the brake assembly in place. The cylinder housing secures to the torque tube and remains stationary along with the stators and pressure plate. The shuttle valve directs system pressure to the pistons, which apply force to the pressure plate. Braking occurs when the pressure plate comes in contact with the stators, which press against the rotors. When brake pressure releases, the piston separates from the pressure plate. Maximum operating hydraulic pressure is 3,000 PSI. For new and worn brakes, the units will begin to produce significant torque at 100 to 150 PSI application pressure.

An automatic adjuster maintains clearance as wear occurs thus keeping a constant operating fluid displacement. Brake wear indicator pins are fastened to the pressure plate and protrude through the cylinder housing. The brake wear indicators provide visual indication of brake lining wear. The brake pads are worn and require replacement when the indicators are flush with the cylinder housing with the brakes applied.

One brake assembly is installed on each main landing gear.

5.0 Wheel Speed Transducer

The wheel speed transducer is an electromechanical unit, which produces a sinusoidal AC voltage output at a frequency of 36 cycles per revolution. The brake control unit uses this information to calculate the speed of the aircraft wheels for use with antiskid protections.

One wheel speed transducer is installed on each main landing gear.

6.0 Emergency Park Brake Valve

The emergency park brake valve is a hydraulic valve with two main purposes:

1. To enable park braking function during unpowered conditions using a hydraulic pressure source to hold the aircraft stationary
2. To enable emergency braking in the event of normal brake system failure

The emergency park brake valve functions such that movement of a lever from the neutral state to the "ON" position causes fluid to flow from the hydraulic pressure source to the brake. Brake pressure is a function of lever position.

One emergency park brake valve is installed on the aircraft in the nose wheel well.

7.0 Digital Antiskid Control Unit

The digital antiskid control unit is a digital (microcontroller) control unit that provides the functions for antiskid control. The digital antiskid control unit contains the antiskid control/built-in-test circuitry for two-wheel control channels. Wheel speed data from both wheel speed transducers is received and processed, and a paired average wheel speed is determined. Antiskid control computations are performed and a single antiskid control signal is provided to the power brake and antiskid valve thus providing skid protection to the left and right wheels. When operating with antiskid protection, both left and right brake pressures will be reduced by virtue of paired wheel antiskid operation.

One digital antiskid control unit is located in the aft cabin attached to the left side fuselage wall.

8.0 Normal Brake System

The normal brake control system consists of a power brake system enhanced by an antiskid system, which provides optimum braking on all runway surfaces by preventing wheel skid. There are two modes of braking: power brake or power brake with antiskid. The brakes will be normally operated in the power brake with antiskid mode. The brakes will operate in the power brake mode when an antiskid control signal is not available.

When the antiskid system is not operational, power brakes without antiskid are available by applying pressure to the top of the rudder pedals which generates control pressure at the master cylinders. Master cylinder stroke is dictated by the fluid displaced by the volume compensator. The amount of brake pressure applied is directly proportional to the control pressure generated by applying force to the rudder pedals.

When the antiskid system is operational, which is considered the normal state of the system, the power brakes are protected from wheel skid. This protection is available when the aircraft wheel speed is above approximately 10 knots and below approximately 165 knots. Wheel skidding, as measured by the wheel speed transducers, is signaled to the digital antiskid control unit which then outputs a signal to the power brake and antiskid valve to reduce both brake pressures simultaneously. The automatic antiskid function returns to the standby mode after wheel skidding stops or brake pedal pressure is reduced below the skid level.

The antiskid system also provides touchdown and locked wheel protection. Touchdown protection inhibits braking until wheel spin-up occurs or weight-on-wheels is determined. Locked wheel protection is provided when aircraft speed is above 25 knots. When either wheel slows to 30% or less of the other wheel velocity, a full brake release of both wheels occurs eliminating the locked wheel condition.

The normal brake control system (power brake/antiskid control) incorporates a built-in-test (BIT). The BIT function allows automatic and continuous monitoring of the antiskid system. The continuous monitor function monitors the antiskid system operational status when it is enabled (ON).

9.0 Emergency/Parking Brake System

The emergency/parking brake system contains a mechanically actuated emergency park brake valve that meters brake pressure to both brakes in proportion

to the emergency/parking brake handle displacement. The emergency/parking brake handle is connected to the valve by a mechanical linkage and a push-pull control cable. There is a shuttle valve between the emergency park brake valve and the brakes. The parking brake function is engaged by pulling the emergency/parking brake handle to the fully extended position. A detent is provided to allow park brake pressure to be maintained without continuous crew input.

The emergency/parking brake system uses accumulator pressure which is separated from system pressure by a one way check valve; therefore the emergency brake system has a different pressure source and hydraulic lines than the normal brake system. The accumulator is charged by hydraulic system pressure. The accumulator has sufficient volume to provide brake applications approximately 6 times in addition to providing hydraulic pressure for nose wheel steering.

A caution message will be displayed if the parking brake is set and brake pressure is below 1500 psi. A separate caution message will be displayed to indicate that there is unintended pressure on the brake system if the aircraft is in the air and the pressure is above 175 psi. A separate advisory message will be displayed to indicate that there is unintended pressure on the brake system if the aircraft is on the ground and the pressure is above 175 psi.

E. WRECKAGE EXAMINATION AND COMPONENT REMOVALS

On June 7, 2023 the NTSB and Honda met at Atlanta Aircraft Salvage in Griffin, GA, to remove brake system components and components with relevant NVM from the airplane. The following components were examined and/or removed:

1.0 Left Tire, Brake Assembly, and Wheel Speed Transducer and Wire Harness

The left tire was inspected. There were no indications of rubber reversion and no signatures of locked or skidding tires (see Figure 1). The tire was P/N M19402, size 17.5 x 5.75 R9, and the tire pressure measured 181 psi.¹ The air was let out of the tire. The left tire inboard and outboard grooves measured a depth of 6/32 inch.²

¹ Per Honda, the unloaded tire pressure requirement is 202-212 psi.

² Per Honda, the minimum tread depth requirement is the bottom of any groove.



Figure 1: Left tire and gear assembly

The left brake assembly had a layer of dirt on it. The left brake was P/N 9006366, S/N "OCT 16-0242". The top brake wear pin measured approximately $\frac{3}{4}$ inch extension with no pressure applied to the brake. The bottom brake wear pin measured approximately $\frac{11}{16}$ inch extension with no pressure applied to the brake.

The left hubcap was secure. The left wheel speed transducer was P/N 140-329, S/N 0240. The wire harness was secure at the transducer connection with the lock pins visible in the witness hole. The wire harness was dirty but remained intact.

The left brake assembly, left wheel speed transducer, and left wheel speed transducer wire harness were removed and retained by Honda for future testing.

2.0 Right Tire, Brake Assembly, and Wheel Speed Transducer and Wire Harness

The right tire was inspected. Half of the tire was fire damaged and the rubber reversion spread down the side walls of the tire. The other half of the tire was intact, and there were no indications of rubber reversion and no signatures of locked or

skidding tires (see Figure 2). The tire was P/N M19402, size 17.5 x 5.75 R9. There was a hole in the sidewall of the tire and therefore no pressure was in the tire. The right tire inboard and outboard grooves measured a depth of 8/32 inch.³



Figure 2: Right side tire and landing gear

The right brake assembly was sooted. The right brake was P/N 9006366, S/N "APR 17-0269". Both brake wear pins measured approximately 1/4 inch extension with no pressure applied to the brake.

The right hubcap was secure. The right wheel speed transducer was P/N 140-329, S/N 0241. The wire harness was secure at the transducer connection with the lock pins visible in the witness hole. The wire harness was thermally damaged and broke into two sections during the transducer removal. The wire harness was disconnected at both ends and the two sections were retained.

The right brake assembly, right wheel speed transducer, and right wheel speed transducer wire harness (in two sections) were removed and retained by Honda for future testing.

³Per Honda, the minimum tread depth requirement is the bottom of any groove.

3.0 Power Brake and Antiskid Valve

The power brake and antiskid valve was P/N 84-023-02 Rev B, S/N 118. The unit was sooted (see Figure 3). The unit was removed and retained by Honda for future testing.

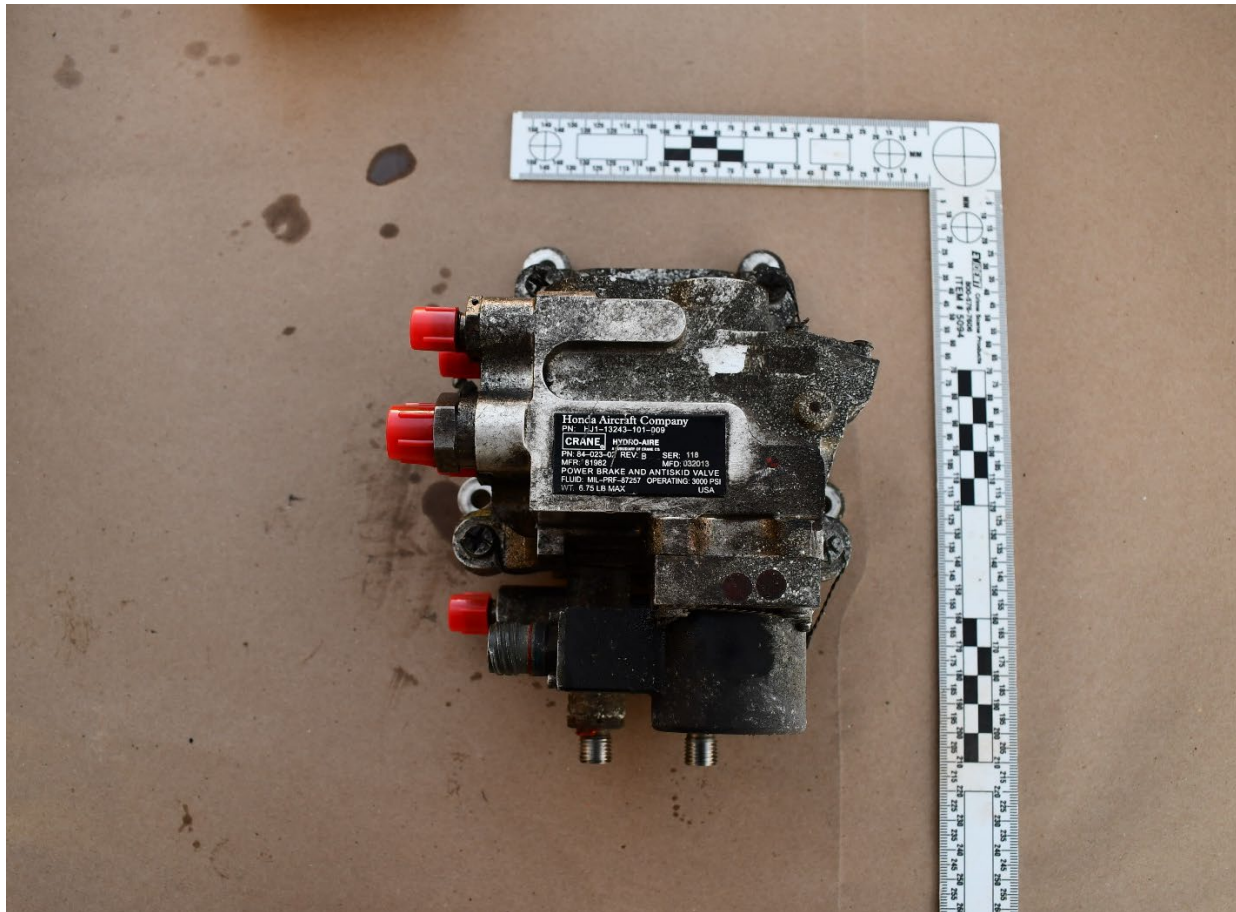


Figure 3: Power brake and antiskid valve

4.0 Brake Shutoff Valve

The brake shutoff valve was sooted (see Figure 4). The unit was P/N 4352, S/N 0067. The unit was removed and retained by Honda for future testing.

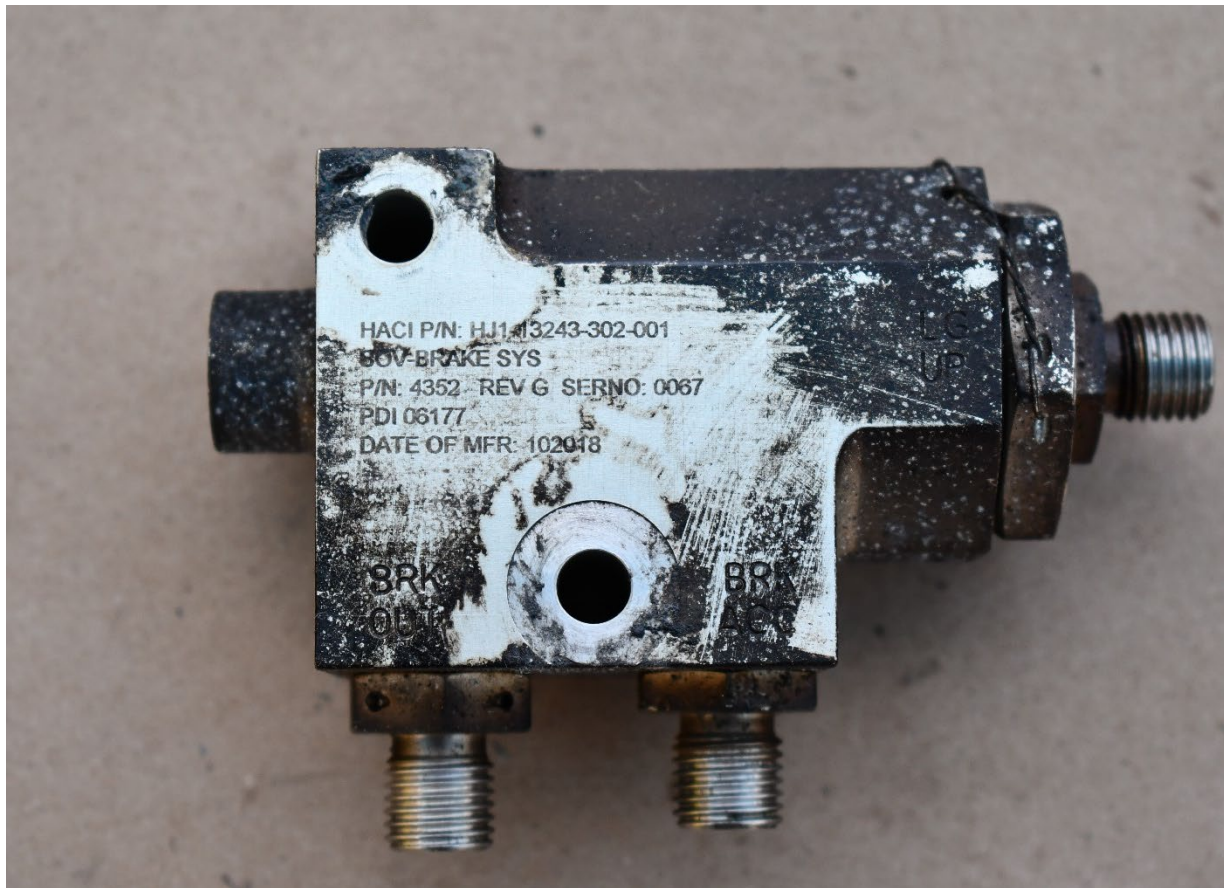


Figure 4: Brake shutoff valve

5.0 Antiskid Control Unit

The antiskid control unit was severely thermally damaged. Through a hole in the case it was observed that the internal circuit card was thermally damaged and the unit was not testable. The unit was not retained for this reason. According to Honda there is no NVM within this unit. The label containing the part number and serial number was either missing or damaged beyond recognition. See Figure 5.



Figure 5: Antiskid control unit

6.0 Primary Flight Displays

The left primary flight display was severely thermally damaged (see Figure 6). The unit was opened. The internal SD card was missing or was unrecognizable due to the thermal damage. All loose chips were bagged and sent to the NTSB recorders laboratory to attempt to extract non-volatile memory (NVM). See the Cockpit Display Specialist's Factual Report found in the public docket for this accident.

The right primary flight display was severely thermally damaged (see Figure 7). The remnants of a possible SD card was located in the internal SD housing. The SD card was bagged and sent to the NTSB recorders laboratory to attempt to extract NVM. See the Cockpit Display Specialist's Factual Report found in the public docket for this accident.



Figure 6: Left side primary flight display



Figure 7: Right side primary flight display

7.0 Nose Wheel Steering Control Unit

The nose wheel steering control unit was removed because it contains NVM related to nose wheel steering faults. The unit was in good condition (see Figure 8). The unit was P/N 40054001-501, S/N SPP000044. The connector pins were straight and clean. The unit was sent to NTSB headquarters for storage, and then later sent to Honda to attempt to extract NVM.



Figure 8: Nose wheel steering control unit

8.0 Emergency Park Brake Valve

The emergency park brake valve was in good condition (see Figure 9). The unit was P/N 059-03007, S/N AWB0079. The unit was removed and retained by Honda for future testing.

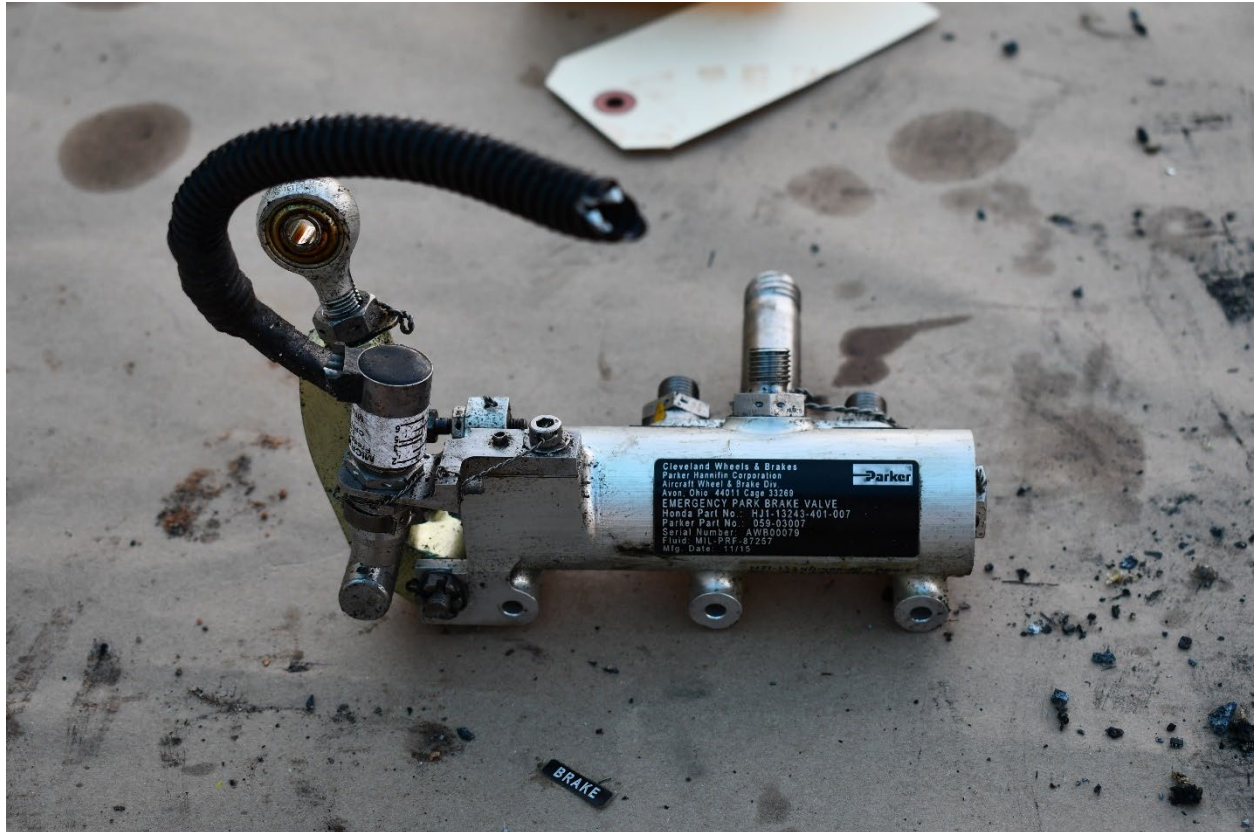


Figure 9: Emergency park brake valve

9.0 Master Cylinders

All four master cylinders were removed from the aircraft and tagged with their location. All were thermally damaged and the labels could not be read on scene (see Figure 10). The right side left pedal master cylinder was blocked with material consistent with melted and extruded piston in the port closest to the piston side. All four master cylinders were retained by Honda for future testing.



Figure 10: Brake master cylinders

10.0 Garmin Integrated Avionics Computers

The Garmin integrated avionics computers were removed because they contain NVM. Both left and right integrated avionics computers were externally thermally damaged and the labels containing the part number and serial number were either missing or damaged beyond recognition (see Figures 11 and 12). Both units were tagged with their location. Both units were removed from the wreckage and sent to the NTSB recorder's laboratory to attempt to extract NVM. See "Cockpit Display Specialist's Factual Report" found in the public docket for this accident for information related to the NVM download attempt.



Figure 11: Left side integrated avionics computer



Figure 12: Right side integrated avionics computer

11.0 Emergency Brake Handle in Flight Deck

The emergency brake handle was observed in the pulled (aft) position.

F. COMPONENT TESTING

On September 6-8, 2023 the NTSB, FAA, and Honda met at the Honda Aircraft facility in Greensboro, NC, to test the brake components removed from the accident airplane. The group determined that the components would need to be tested individually due to the possibility of internal damage caused by the post-accident fire. In addition, a hydraulic line discovered during an airport inspection after the wreckage was removed from the airport was examined and identified. The following components were examined and/or functionally tested:

1.0 Left Wheel Speed Transducer

The left wheel speed transducer was P/N 140-329 (Honda P/N HJ1-13241-102-001), S/N 0240. The date of manufacturer was 11/2015. The transducer was in good condition with no corrosion observed. There was a darkish stain noted around one of the set screw holes. The electrical pins were straight and clean. The transducer rotated freely. The unit's resistance was measured at 411 Ohms which was within limits required by the Test Procedure TP140-329. An attempt was made to test the unit using Honda lab equipment but the test did not produce repeatable results. The unit was sent to Crane for testing on the manufacturer's test equipment. The unit passed all portions of the Test Procedure.

2.0 Right Wheel Speed Transducer

The right wheel speed transducer was P/N 140-329 (Honda P/N HJ1-13241-102-001), S/N 0241. The date of manufacturer was 11/2015. The transducer was in good condition with no corrosion observed. The electrical pins were straight and clean. The transducer rotated freely. The unit's resistance was measured at 405 Ohms which was within limits required by Test Procedure TP140-329. An attempt was made to test the unit using Honda lab equipment but the test did not produce repeatable results. The unit was sent to Crane for testing on the manufacturer's test equipment. The unit passed all portions of the Test Procedure.

3.0 Left Wheel Speed Transducer Harness

The left wheel speed transducer harness was P/N HJ1-13211-053-005. It was dirty but did not appear to have any significant physical damage. It was intact from the transducer connector to the upper gear harness connector. The left transducer from the accident was connected to the harness. Continuity was verified by connecting a Fluke meter to the upper gear harness connector and measuring the resistance of the attached left wheel speed transducer. The resistance measured was

approximately 400 Ohms, which was within the requirements of Test Procedure TP140-329. The harness was then tested for insulation resistance by applying 500 VDC and measuring resistance to the ground connector. The resulting insulation resistance was more than 550 M Ω , which is greater than the requirement value of 200 M Ω minimum.

4.0 Right Wheel Speed Transducer Harness

The right wheel speed transducer wire was severed approximately 6 inches from the transducer connector. The main harness (P/N HJ1-13211-053-005) was severed approximately 18 inches from the weight on wheels proximity switch which remained connected to the harness. The harness was discolored and some of the wire insulation was missing. Due to the damage and severed locations continuity checks were not attempted.

5.0 Left Brake Assembly

The left brake assembly was P/N 90006366 Rev E, S/N "OCT 16-0242". No heat damage or sooting was observed on this brake assembly. Safety wire was observed on both bleeder fittings, both plugs, and both hydraulic fittings. The brake stack had a layer of dirt on it. An external visual inspection found that the friction material appeared to be in good condition. The rotors were free to rotate. In the as-received condition the hydraulic ports were capped but there was no hydraulic fluid in the unit.

Pressure was applied to the brake assembly using both the normal and emergency brake ports independently. At 500, 1000, 1750, and 3000 psi the unit was inspected for leaks, with none observed. The rotors were locked by 500 psi. At 1750 and 3000 psi applied pressure to the forward brake port the wear pins were measured, with the upper pin measurement at 0.62 inch and the lower pin measurement at 0.65 inch at both pressure readings. All 4 pistons extended when pressure was applied. When pressure was released the brake stack relaxed and the rotors were again free to rotate. The wear pin extensions were again measured with no hydraulic pressure applied, and the upper wear pin measured 0.76 inch extension and the lower wear pin measured 0.78 inch extension.

6.0 Right Brake Assembly

The right brake assembly was P/N 90006366 Rev E, S/N "APR 17-0269". Sooting was observed on this brake assembly and material consistent with melted aluminum was located around the hydraulic fittings. Safety wire was observed on both bleeder fittings, both plugs, and both hydraulic fittings. The safety wire around the hydraulic fittings had to be cut to remove the melted material noted above. An external visual inspection found that the friction material showed evidence of wear.

The rotors were free to rotate. In the as received condition the hydraulic ports were capped but there was no hydraulic fluid in the unit.

Pressure was applied to the brake assembly using both the normal and emergency brake ports independently. At 500, 1000, 1750, and 3000 psi the unit was inspected for leaks, with none observed. The rotors were locked by 500 psi. At 1750 and 3000 psi the wear pins were measured, with the upper pin measurement at 0.20 inch and the lower pin measurement at 0.15 inch at both pressure readings. All 4 pistons extended when pressure was applied. When pressure was released the brake stack relaxed and the rotors were again free to rotate. The wear pin extensions were again measured with no hydraulic pressure applied, and the upper wear pin measured 0.30 inch extension and the lower wear pin measured 0.27 inch extension.

7.0 Brake Shutoff Valve

The brake shutoff valve was P/N 4352 Rev G (Honda P/N HJ1-13243-302-001), S/N 0067. The manufacture date was Oct 2018. The unit was heavily sooted. Dust caps were covering all ports. Safety wire was present on the end cap. The "BRK OUT" fitting was checked with a wrench and was seated but easy to rotate. Prior to testing the brake shutoff valve, the piston poppet was observed in the open position (valve was not in the shut off position).

3000 psi hydraulic pressure was applied to both the brake port chamber and the landing gear up chamber in isolation, and no leaks were observed. With 2500 psi to the brake accumulator port chamber, 1700 psi was applied to the landing gear up chamber, and flow from the brake out port stopped. The test setup did not allow for the determination of the exact shut off pressure that resulted in the pressure stop to the brake; however, the set up did allow for the test to demonstrate that the valve operated to the Acceptance Test Procedure (ATP4352, Rev B) specification that this would occur below 1700 psi. When the pressure was removed from the landing gear up chamber (0 psi), the flow returned to the brake port.

8.0 Emergency Park Brake Valve

The emergency park brake valve was P/N 059-03007 (Honda P/N HJ1-13243-401-007), S/N AWB00079. Date of manufacture was 11-2015. The unit was in good condition with no damage or sooting observed. All safety wire was present. The unit was connected to an oscilloscope and system pressure, brake pressure, and valve input lever position were recorded. With 3000 psi input pressure, there was no output pressure when the valve was closed, and 3000 psi output pressure when the valve was fully open. The valve lever was then manually actuated through its full stroke and the output pressure was recorded and compared to the ATP (ATP6158, Rev C) requirement envelope. The data is plotted in Figure 13. The ATP requirement

envelope for the lever stroke vs output pressure curve is only applicable while applying brakes. Deviations are acceptable during the release of the brakes.

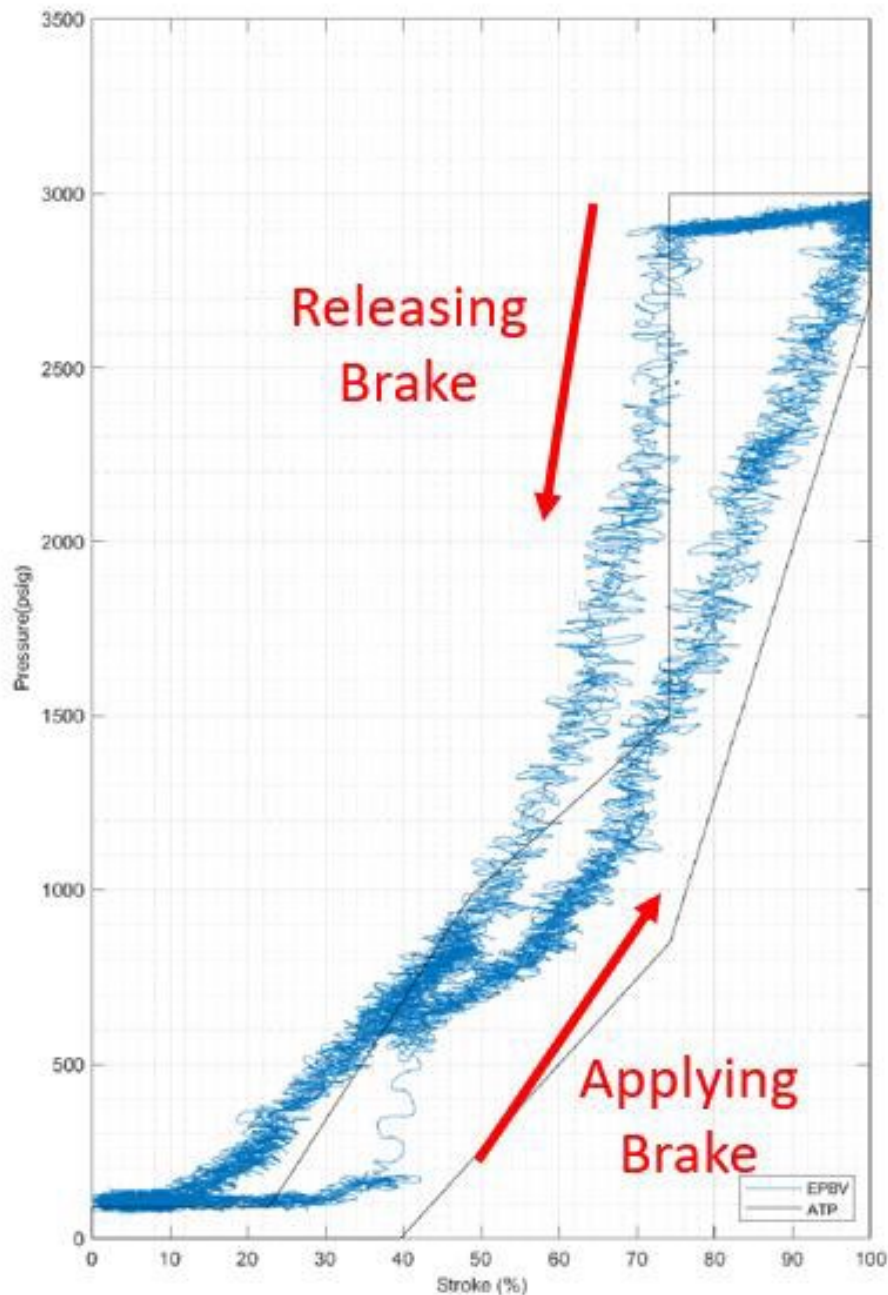


Figure 13: Emergency park brake valve lever Stroke vs. Output pressure. The grey box represents the ATP requirement envelope while applying brake pressure only. Figure used with permission from Honda and Crane.

9.0 Power Brake and Antiskid Valve

The power brake and antiskid valve was P/N 84-023-02 Rev B (Honda P/N HJ1-13243-101-009), S/N 118. The unit was heavily sooted. All safety wire was present.

Connector pins were straight and clean. The unit was shipped with dust caps. The caps were removed and all fluid was poured out. The ports were cleaned with alcohol and some small FOD specs were observed. Significant FOD was observed in the brake right port fitting, which provides output pressure to the brake assembly (see Figure 14). When the FOD was flushed out during testing (see next paragraph) it broke into small pieces in the hydraulic fluid. It is noted that the FOD is on the downstream side of a 10 micron filter in this port fitting. Computed tomography scans (described later in this section) revealed that the screen was intact.



Figure 14: FOD observed in the brake right port fitting of the power brake and antiskid valve. Photo courtesy of Honda.

To understand the effects of the material observed in the brake right port fitting, the power brake valve was connected to the test bench. With only return pressure applied to the brake right port (40 psi), the port dripped fluid and some material came out with the fluid. With 200 psi input pressure, a steady stream of hydraulic fluid was coming from the right brake port, and a lot of the material came out with the fluid. The port was again observed and now looked clean.

The valve was then subjected to pressure testing to ensure there was no damage to the manifold or seals that would result in external leakage. The unit was successfully pressure tested up to 3000 psig. The unit was then connected to the test bench and an oscilloscope. The supply pressure, master cylinder pressure, brake pressure, and antiskid voltage were recorded.

The valve test was set up to test the right brake functionality first. The valve was supplied with an input pressure of 3000 psig. The master cylinder in the test stand was actuated to provide an input pressure to the master cylinder right port. The master cylinder pressure vs brake pressure and antiskid current vs brake pressure were plotted and compared to the ATP requirement envelopes. A sample of the data plots can be found in Figures 15 and 16.

After the right brake functional testing was completed, the test stand was configured in the same test setup for the left brake functional testing. A sample of the plots from those test runs are included in Figures 17-20. Figures 18-20 show that the Antiskid Current vs. Brake Pressure plot for the left brake demonstrated a large hysteresis when returning to 0 mA. The performance curve deviates outside of the ATP requirement envelope and it also deviates from the 3mA max hysteresis requirement. According to Crane, this anomaly would not prevent the application of brakes nor the removal of pressure during skidding events; however, the hysteresis may lead to performance degradation due to the decreased pressure application for a given current input.

It was unknown if the test setup or equipment used during the testing at Honda contributed to the unexpected test results, so the valve was sent to Crane to be tested per ATP TP140-329 on the manufacturer's test equipment.⁴ On 11/08/2024 the unit passed all portions of the ATP. A Current vs Pressure plot was made prior to the ATP and after the ATP. All plots were within limits both times. The initial Current vs Pressure plot (created prior to starting the ATP) can be found in Figure 21.

To further understand the test result observed on the Honda test equipment, the valve was CT scanned (see Computed Tomography Specialist's Factual Report in the public docket for this investigation). The only anomaly identified was an area of potential low-density material in the left master cylinder metering valve, but later

⁴ The test setup at Honda was made specifically to facilitate this investigation.

teardown of the valve did not reveal any foreign object debris or other concerns in this area. The area in question matched the location of a manufacturing hole on the flange surface of the slide. It is also possible that the anomaly was an artifact of the scan.

The valve was disassembled at Crane and both metering valves and both antiskid valves were inspected. There were no failed components, large FOD, or other concerning anomalies found during the disassembly. All o-rings were fully intact although some demonstrated permanent deformation (according to Crane this is not unexpected for in-service units). Minor surface scratches were identified on the metering valve pistons and on the metering edge of both left and right antiskid valve slides.

Honda certification flight test data shows that the braking skid threshold on a dry smooth runway occurs at an average brake pressure of 900 to 1,000 psi. A skid on a wet runway would be expected to occur at slightly lower brake pressures.

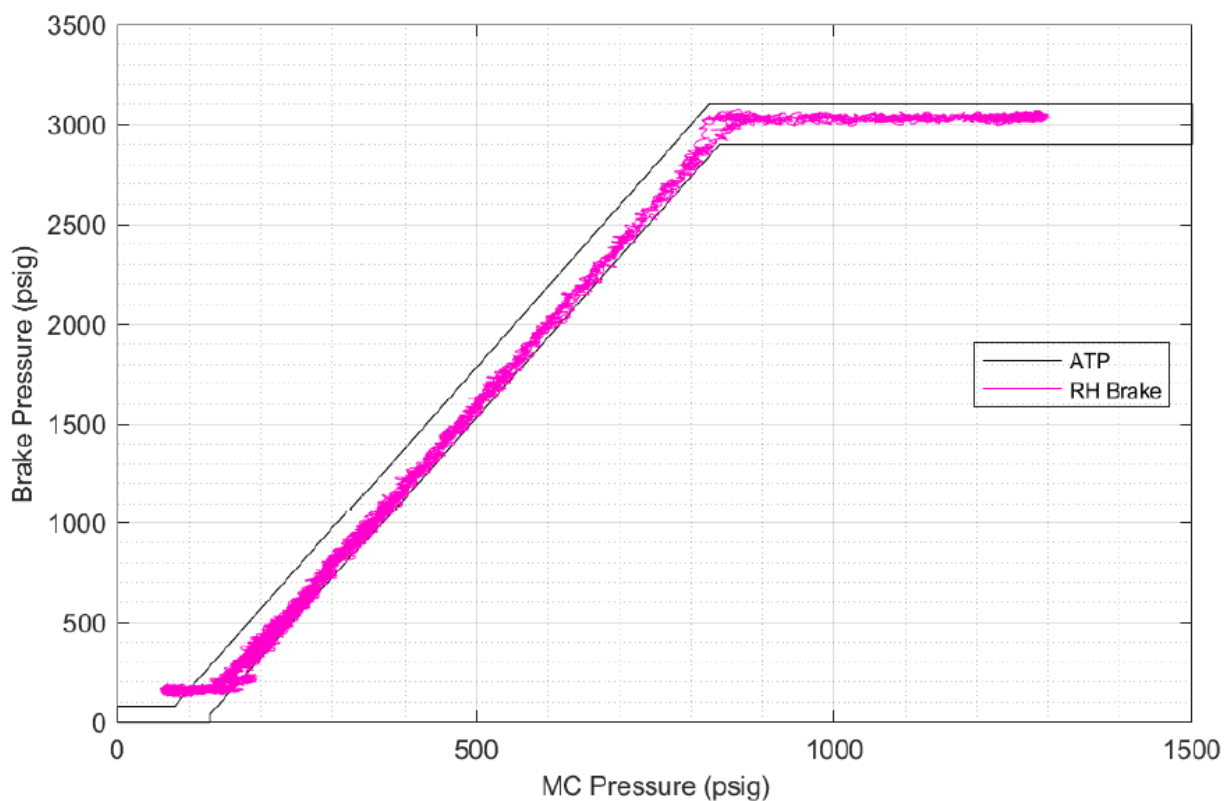


Figure 15: Power brake and antiskid valve master cylinder Pressure vs. Brake pressure for right brake. Figure used with permission from Honda and Crane.

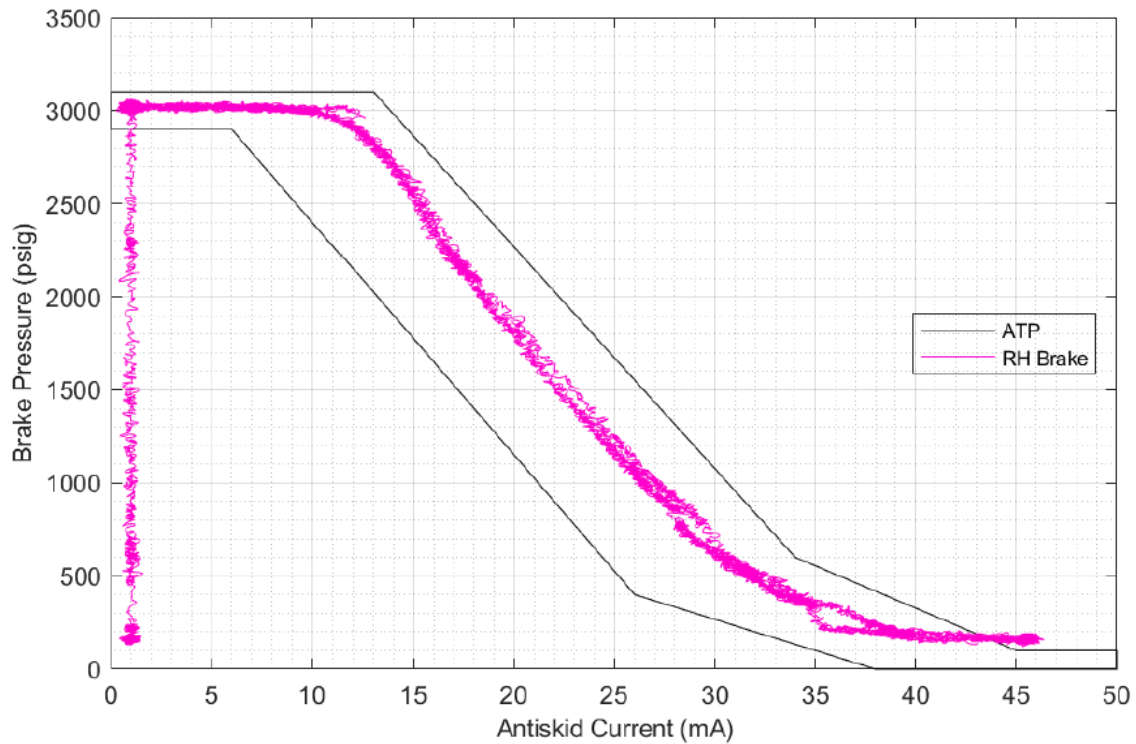


Figure 16: Power brake and antiskid valve Antiskid Current vs. Brake Pressure for right brake. Figure used with permission from Honda and Crane.

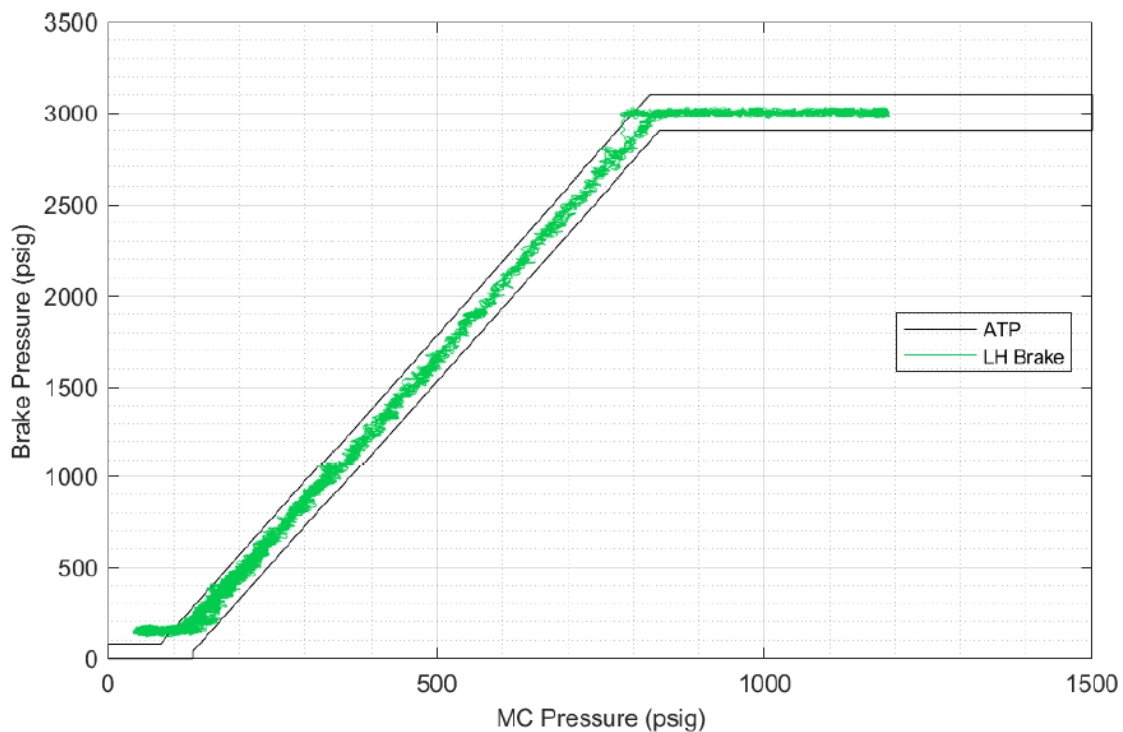


Figure 17: Power brake and antiskid valve Master Cylinder Pressure vs. Brake Pressure for left brake. Figure used with permission from Honda and Crane.

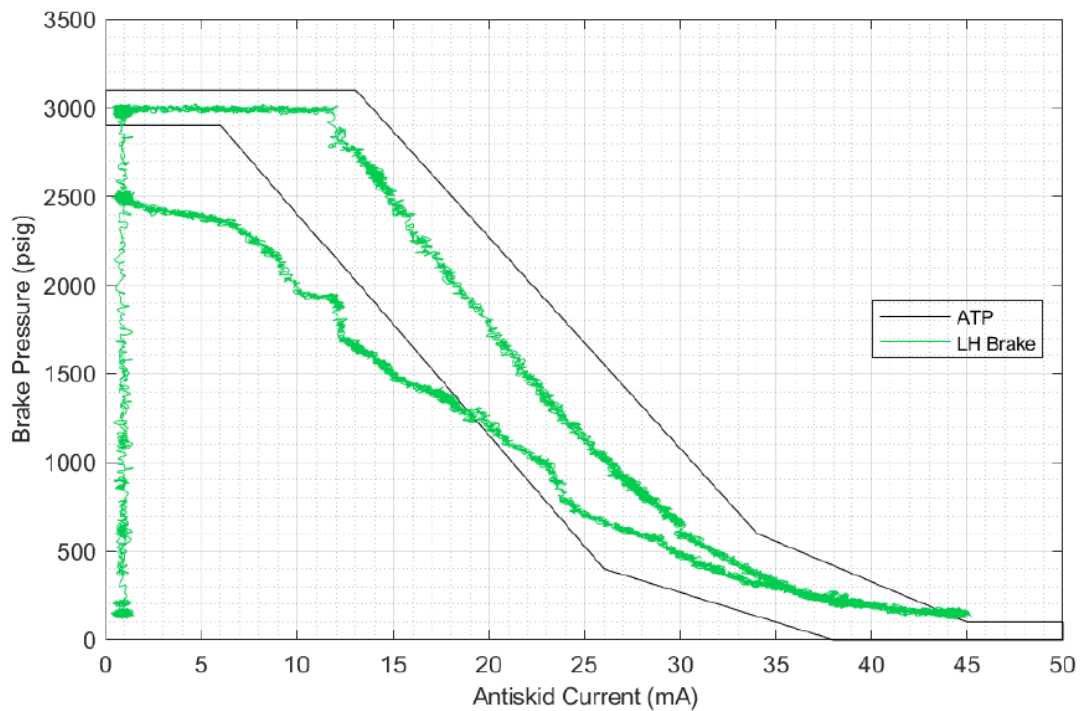


Figure 18: Power brake and antiskid valve Antiskid Current vs. Brake Pressure for left brake (example 1 of 3). Figure used with permission from Honda and Crane.

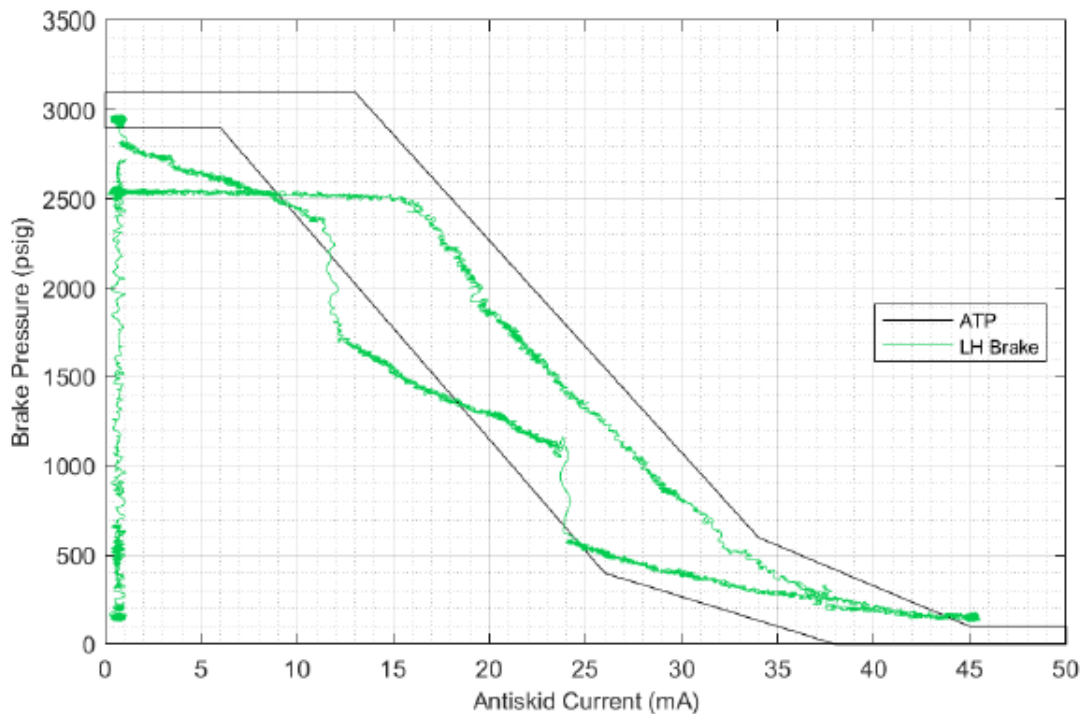


Figure 19: Power brake and antiskid valve Antiskid Current vs. Brake Pressure for left brake (example 2 of 3). Figure used with permission from Honda and Crane.

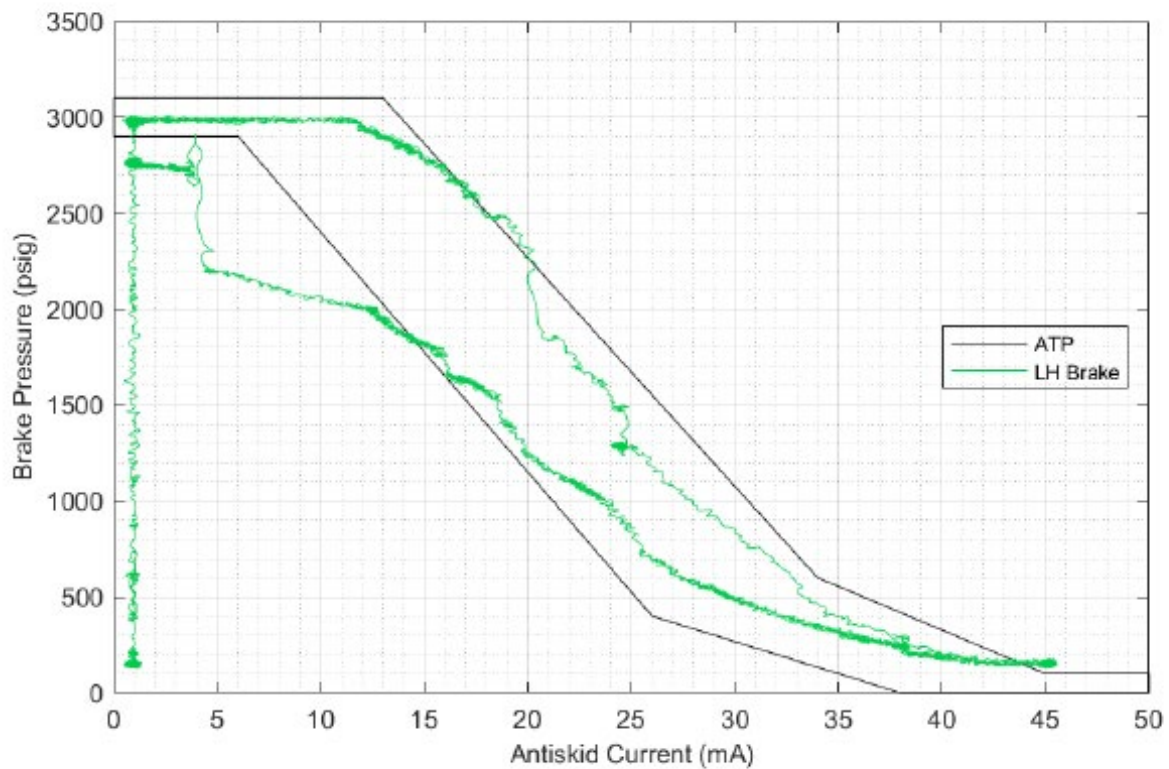


Figure 20: Power brake and antiskid valve Antiskid Current vs. Brake Pressure for left brake (example 3 of 3). Figure used with permission from Honda and Crane.

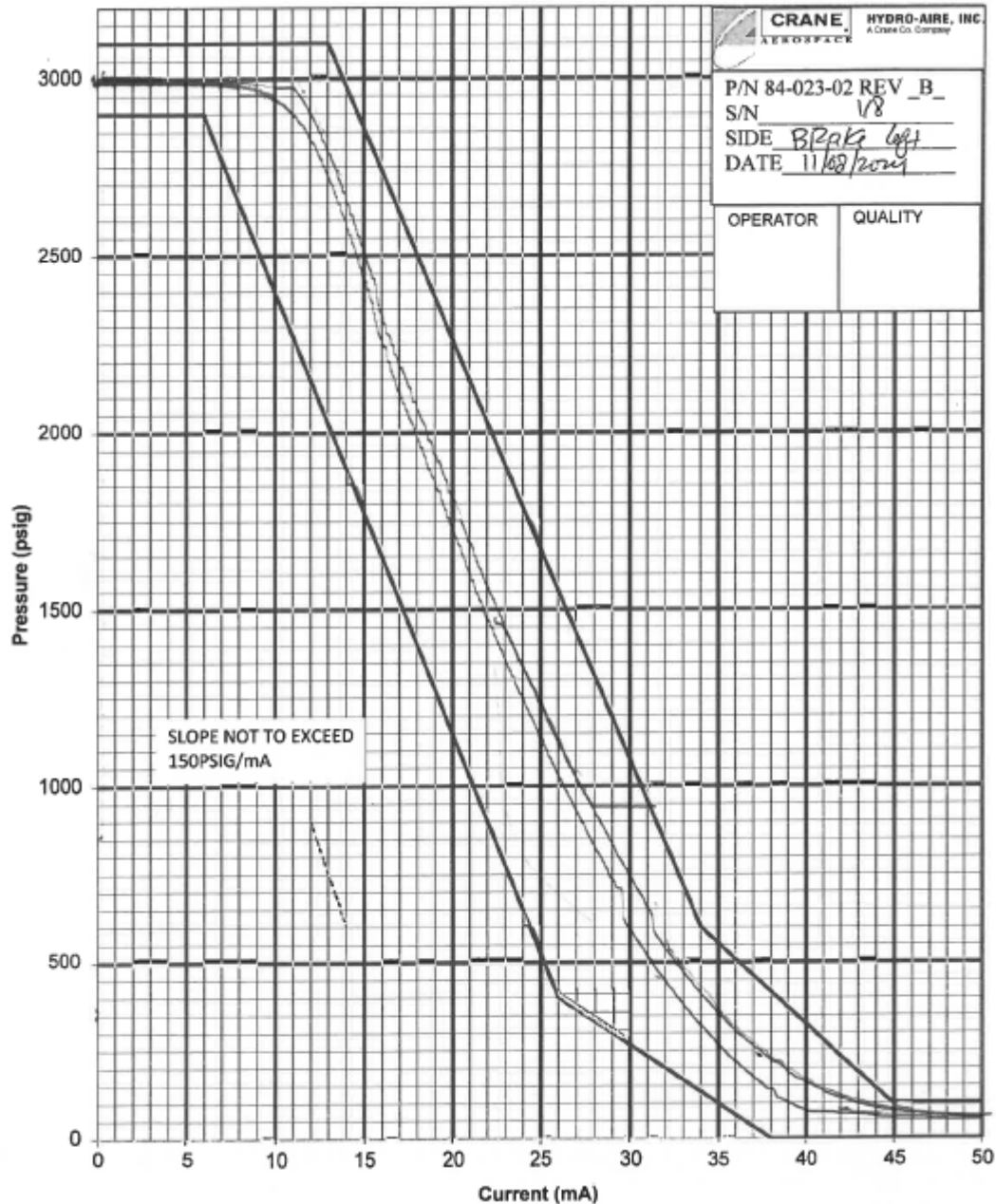


Figure 21: Power brake and antiskid valve Antiskid Current vs. Brake Pressure for left brake. Plot made at Crane prior to the ATP test. Figure used with permission from Crane.

10.0 Master Cylinder - Pilot Left Brake Position

The master cylinder was P/N HJ1-13243-201-005, S/N AWB00292. The unit was heavily sooted. All safety wire was intact. Dust covers were installed on the hydraulic ports. The ports were dry. The ports were flushed with alcohol with no visible FOD identified. The piston chamber was cleaned with alcohol prior to testing.

The unit was connected to the test bench and flushed. Some small specs of FOD came out during the flush.

The master cylinder was supplied with inlet pressure at 40 psig. The master cylinder was manually actuated to varying targeted pressure outputs (approximately 350, 750, and 1500 psi) and held steady for a short duration. The intention of the test was to hold the master cylinder in a steady position and monitor the pressure to ensure it was not dropping, as that would be indicative of a leak within the master cylinder. A sample of the master cylinder stroke and output pressure time history can be found in Figure 22.

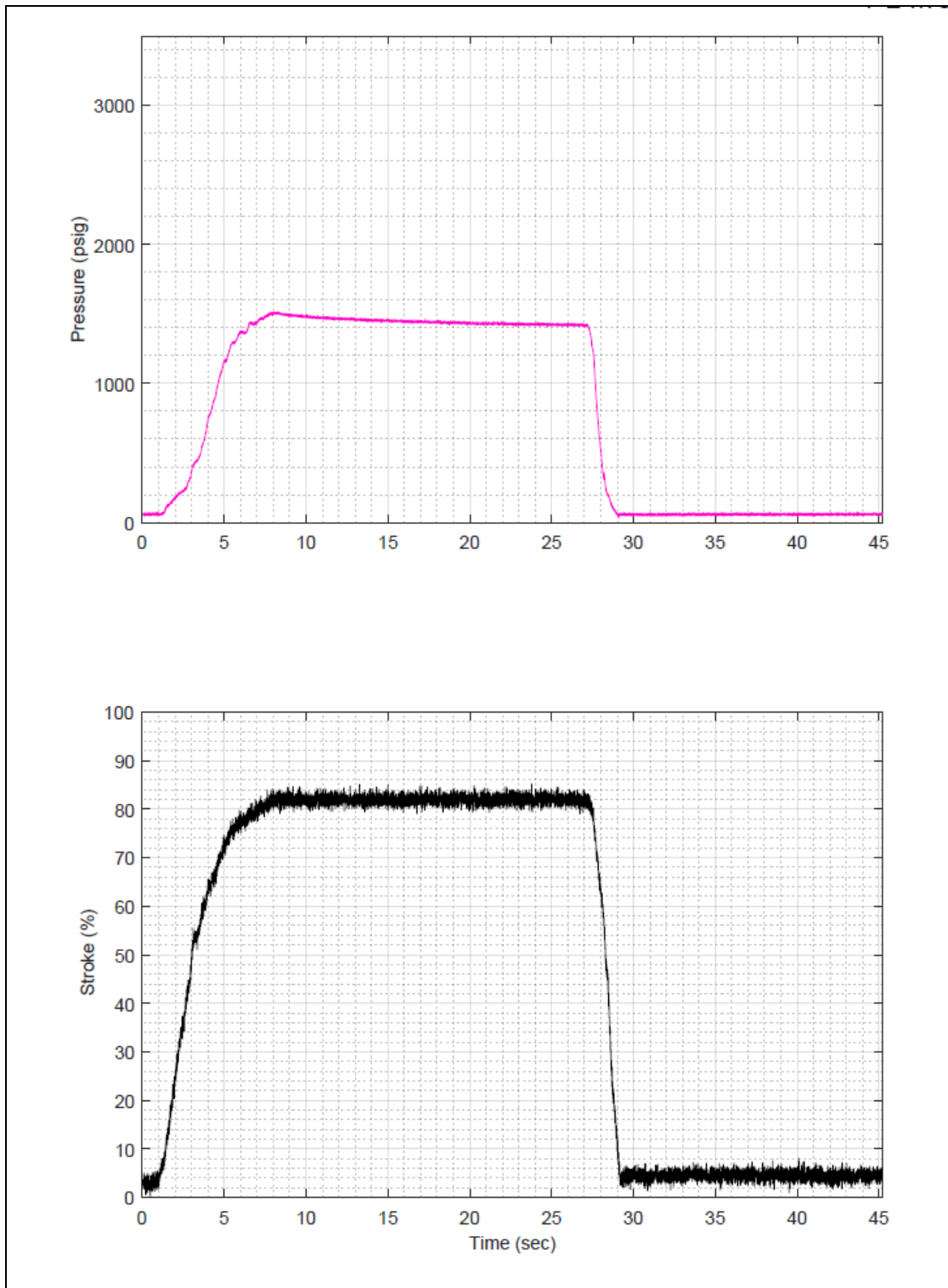


Figure 22: Pilot left master cylinder Time vs Stroke at approximately 1500psi target pressure. Figure used with permission from Honda and Crane.

11.0 Master cylinder - Pilot Right Brake Position

The master cylinder was P/N HJ1-13243-201-005, S/N AWB00294. The unit was heavily sooted. All safety wire was intact. Dust covers were installed on the hydraulic ports. The ports were dry. FOD was identified in the top of the outlet port (see Figure 23). The piston chamber was cleaned with alcohol prior to testing and significant amounts of fine dark colored specs of FOD were observed. The FOD had some shiny features and did not visually appear to be consistent with an o-ring material. It is noted that possible contaminants from the surrounding heat damaged area could have been introduced during the component removal and capping process.

The master cylinder was supplied with inlet pressure at 40 psig. The master cylinder was manually actuated to varying targeted pressure outputs (approximately 350, 750, and 1500 psi) and held steady for a short duration. The intention of the test was to hold the master cylinder in a steady position and monitor the pressure to ensure it was not dropping, as that would be indicative of a leak within the master cylinder. A sample of the master cylinder stroke and output pressure time history can be found in Figure 24.



Figure 23: FOD in outlet port fitting of the pilot right master cylinder. Picture courtesy of Honda.

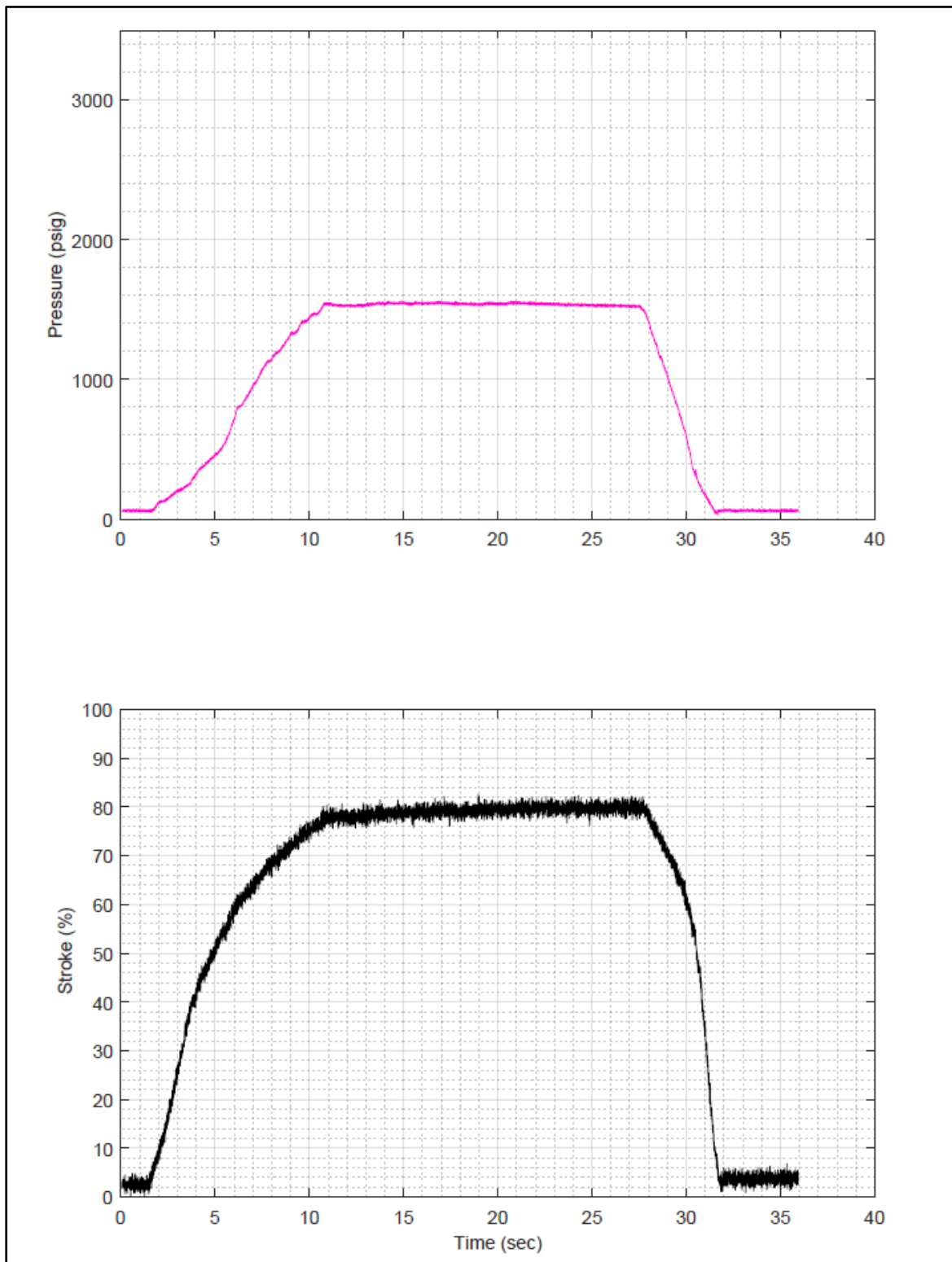


Figure 24: Pilot right master cylinder Time vs Stroke at approximately 1500psi target pressure. Figure used with permission from Honda and Crane.

12.0 Master cylinder - First Officer Left Brake Position

The label was missing from this master cylinder. The unit was heavily sooted. All safety wire was intact. Dust covers were installed on the hydraulic ports. A white material, consistent with hardened plastic, was extruding out the inlet port fitting (see Figure 25). This FOD could not be removed, and the piston was incapable of being actuated by hand. The unit could not be tested and the decision was made to perform a teardown inspection. Disassembly of the master cylinder revealed that the FOD material was the melted piston, P/N 148-09500, of the master cylinder. According to the manufacturer, the material is PEEK per MIL-P-46183 Type 1.⁵ Aside from the melted material, no other anomalies were identified during the teardown.



Figure 25: Piston extrusion from the first officer left brake master cylinder inlet port fitting. Picture courtesy of Honda.

⁵ PEEK MIL-P-46183 Type 1 is a polyetheretherketone plastic.

13.0 Master cylinder - First Officer Right Brake Position

The master cylinder part number and serial number could not be read due to damage to the label. The unit was heavily sooted. All safety wire was intact. Dust covers were installed on the hydraulic ports. The ports were dry. The ports were flushed with alcohol with a few small specs of FOD were observed. The piston chamber was cleaned with alcohol prior to testing. The unit was connected to the test bench and flushed. No FOD was observed during the flush.

The master cylinder was supplied with inlet pressure at 40 psig. The master cylinder was manually actuated to varying targeted pressure outputs (approximately 350, 750, and 1500 psi) and held steady for a short duration. The intention of the test was to hold the master cylinder in a steady position and monitor the pressure to ensure it was not dropping, as that would be indicative of a leak within the master cylinder. A sample of the master cylinder stroke and output pressure time history can be found in Figure 26.

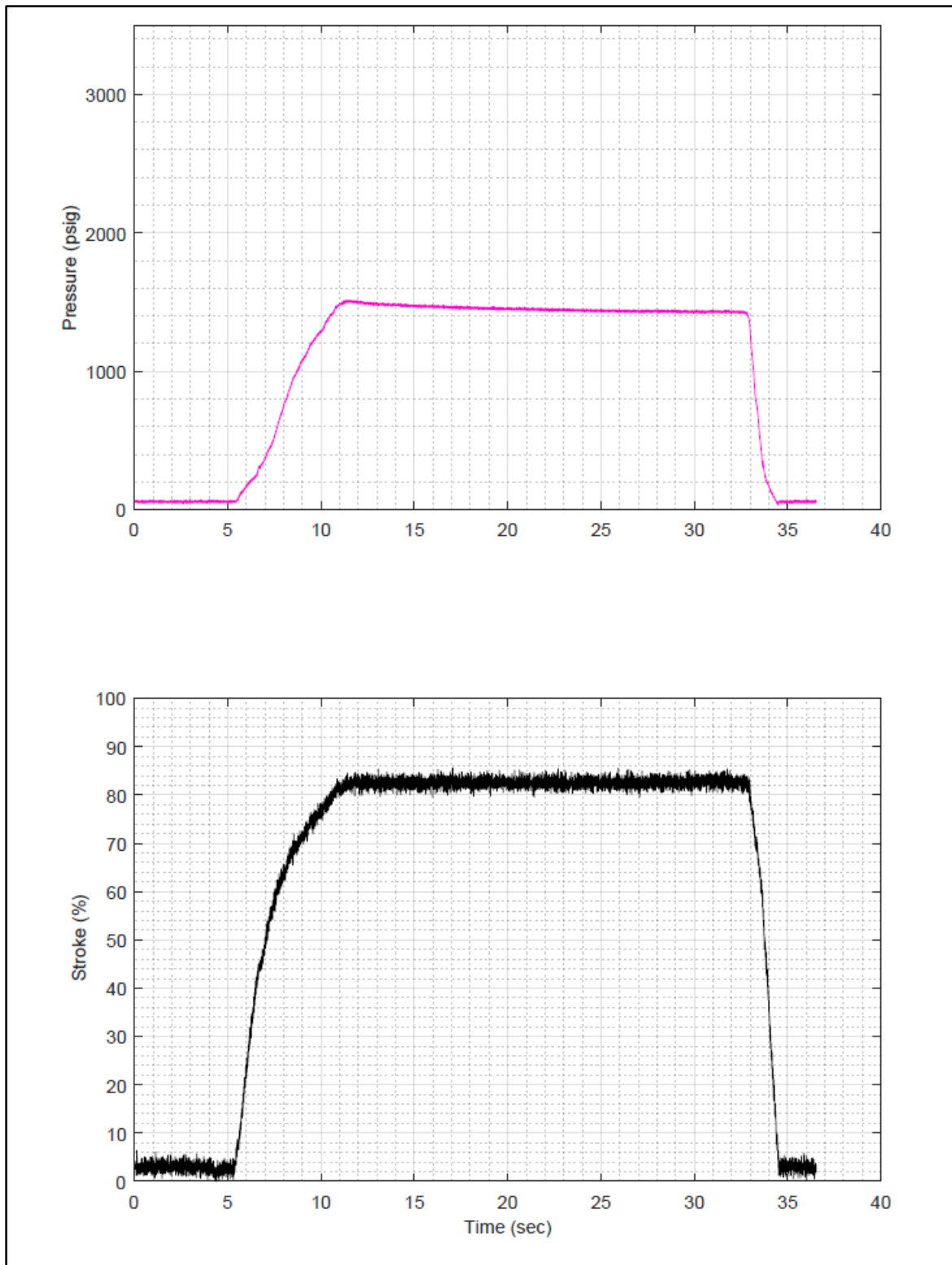


Figure 26: Co-pilot right master cylinder Time vs Stroke at approximately 1500psi target pressure. Figure used with permission from Honda and Crane.

14.0 Additional Hydraulic Line

A part that was shipped to the NTSB from a representative of the South Carolina Aeronautics Commission was examined. The part was found during an inspection of the Summerville Airport after the aircraft wreckage had been removed. The part was located in the rocks where the aircraft came to rest. It was approximately 15 inches of steel braided hose connected to approximately 1 foot of hydraulic tubing. The Teflon inside the braided hose was missing and only the steel braid remained. The braid was heat damaged and stained brown. Honda identified the part as a landing gear door closed hydraulic line P/N HJ1-13230-264-103.

15.0 Nose Wheel Steering Control Unit

The nose wheel steering unit, P/N 40054001-501, S/N SPP00044, non-volatile memory was downloaded by Honda. There is no date/time stamp associated with the data; however, there is a "time since power up" counter displayed in seconds.

The data obtained from the download can be found in Attachment 1. The numbers at the top of the file are the most recent. The failure count is for a single nose wheel steering control unit power cycle (the number 9 would represent the 9th fault to be logged for that power cycle, and a subsequent 1 would represent the start of a new power cycle that contained a fault).

Index numbers 1-21 have "time since power up" intervals of 0 to 71 seconds. These would not be attributed to the accident landing because of the short duration since power up. Honda stated that the test bench used to download the NVM required the nose wheel steering unit to be powered up but did not provide system inputs, including inputs from the rudder pedal input linear variable differential transformers (LVDTs) (XDCR 1/2), steering control valve actuator (SCVA) LVDT, or the nose wheel steering shut off valve (SOV). The nose wheel steering unit would record the lack of these inputs as faults.

Index numbers 22-29 had a "time since power up" of approximately 3132 seconds, which equates to approximately 52.2 minutes. The following fault definitions were provided by Honda:

Monitor / Control CSCI XDCR Difference Monitor:

This monitor is comparing the position of the rudder pedal input LVDT 1 and LVDT 2 and flagging a fault if they differ by more than 15%.

Monitor / Control CSCI XDCR2 Monitor:

This fault is logged when the XDCR2 monitor detects an invalid input from rudder pedal input LVDT 2 for 90 msec.

Shut Off Valve Monitor:

The shut off valve monitor function is verifying that the nose wheel steering shut off valve position matches the input command.

Monitor / Control CSCI SCVA LVDT Monitor:

This fault is logged when the monitor detects an invalid input from the steering control valve actuator LVDT for 90 msec.

During the accident sequence the nose landing gear departed the airplane and was found near the right-side empennage. Honda stated that the faults recorded in index numbers 23 and 27-29 are consistent with the failure of a wire harness for the nose wheel steering shut off valve and steering control valve actuator LVDT that is attached to the nose landing gear assembly. In addition, the rudder pedal input LVDTs are mounted on the center keel and to the forward rudder control sector. Index numbers 22 and 24-26 would be expected if a mis-compare between the two rudder pedal input LVDTs occurred due to any deformation in this area. None of the faults for this flight leg were related to the braking or antiskid systems.

Earlier flight legs contained nose landing gear weight-on-wheels (WOW) faults. These faults occur when the nose landing gear WOW status is on-ground and both main landing gear WOW statuses are in-air. The nose landing gear WOW condition is used for steering touchdown protection only. Neither the brake system nor the antiskid system uses inputs from the nose landing gear WOW condition. According to Honda WOW faults may be recorded during maintenance activities where the aircraft is put in the in-air state.

Earlier flight legs also contained nose landing gear centering faults. These faults occur when the nose landing gear WOW is in-air and the steering collar on the nose gear is moved outside the Centering Monitor angular limits (greater than $\pm 2^\circ$ from center). Honda stated that centering faults may be recorded during towing operations where the torque link on the nose landing gear is disconnected.

Submitted by:

Adam Huray
Aircraft Systems Investigator

APPENDIX A

INDEX	FAILURE COUNT	NAME OF MONITOR	SECONDS
1	17		71
2	16		71
3	15		71
4	14	FSL-5 Control CSCI Receive Data Monitor	5
5	13	FSL-4 Monitor CSCI Reference Aircraft Speed Monitor	5
6	12	FSL-5 Monitor CSCI Receive Data Monitor	5
7	11	FSL-4 Control CSCI SCVA LVDT Monitor	0
8	10	FSL-4 Control CSCI XDCR2 Monitor	0
9	9	FSL-4 Control CSCI XDCR1 Monitor	0
10	8	FSL-5 Control CSCI R_VEL signal Voltage Monitor	0
11	7	FSL-4 Monitor CSCI SCVA LVDT Monitor	0
12	6	FSL-4 Monitor CSCI SCVA LVDT Monitor	0
13	5	FSL-4 Monitor CSCI XDCR2 Monitor	0
14	4	FSL-4 Monitor CSCI XDCR2 Monitor	0
15	3	FSL-4 Monitor CSCI XDCR1 Monitor	0
16	2	FSL-4 Monitor CSCI XDCR1 Monitor	0
17	1	FSL-5 Monitor CSCI R_VEL signal Voltage Monitor	0
18	4	FSL-4 Monitor CSCI SOV Monitor	3
19	3	FSL-4 Control CSCI SCVA LVDT Monitor	0
20	2	FSL-4 Monitor CSCI SCVA LVDT Monitor	0
21	1	FSL-4 Monitor CSCI SCVA LVDT Monitor	0
22	8	FSL-4 Control CSCI XDCR Difference Monitor	3133
23	7	FSL-4 Monitor CSCI SOV Monitor	3133
24	6	FSL-4 Control CSCI XDCR2 Monitor	3132
25	5	FSL-4 Monitor CSCI XDCR Difference Monitor	3132
26	4	FSL-4 Monitor CSCI XDCR2 Monitor	3132
27	3	FSL-4 Control CSCI SCVA LVDT Monitor	3132
28	2	FSL-4 Monitor CSCI SCVA LVDT Monitor	3131
29	1	FSL-4 Monitor CSCI SCVA LVDT Monitor	3131
30	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
31	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
32	4		4558
33	3	FSL-5 Monitor CSCI Centering Monitor	4558
34	2	FSL-5 Control CSCI NLG WOW Error Monitor	135
35	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	135
36	4		3
37	3	FSL-5 Monitor CSCI Centering Monitor	2
38	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
39	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
40	2		2954
41	1	FSL-5 Monitor CSCI Centering Monitor	2953
42	2	FSL-5 Control CSCI NLG WOW Error Monitor	1

43	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
44	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
45	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
46	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
47	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
48	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
49	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
50	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
51	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
52	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
53	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
54	6		0
55	5		0
56	4	FSL-5 Control CSCI Centering Monitor	62
57	3	FSL-5 Monitor CSCI Centering Monitor	62
58	2		62
59	1	FSL-5 Monitor CSCI Centering Monitor	52
60	8		123
61	7		123
62	6	FSL-5 Control CSCI Centering Monitor	104
63	5	FSL-5 Monitor CSCI Centering Monitor	104
64	4		104
65	3	FSL-5 Control CSCI NLG WOW Error Monitor	95
66	2	FSL-5 Monitor CSCI NLG WOW Error Monitor	94
67	1	FSL-5 Monitor CSCI Centering Monitor	94
68	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
69	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
70	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
71	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
72	4		3
73	3	FSL-5 Monitor CSCI Centering Monitor	2
74	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
75	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
76	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
77	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
78	10		207
79	9		207
80	8	FSL-5 Control CSCI Centering Monitor	199
81	7	FSL-5 Monitor CSCI Centering Monitor	199
82	6		199
83	5	FSL-5 Monitor CSCI Centering Monitor	189
84	4		166
85	3	FSL-5 Monitor CSCI Centering Monitor	165
86	2		155
87	1	FSL-5 Monitor CSCI Centering Monitor	154
88	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
89	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1

90	8		23
91	7		22
92	6	FSL-5 Control CSCI Centering Monitor _	13
93	5	FSL-5 Monitor CSCI Centering Monitor _	13
94	4		12
95	3	FSL-5 Monitor CSCI Centering Monitor _	2
96	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
97	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
98	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
99	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
100	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
101	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
102	2	FSL-5 Control CSCI NLG WOW Error Monitor	1642
103	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1642
104	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
105	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
106	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
107	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
108	2	FSL-5 Control CSCI NLG WOW Error Monitor	125
109	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	124
110	6	FSL-5 Control CSCI NLG WOW Error Monitor	4
111	5	FSL-5 Monitor CSCI NLG WOW Error Monitor	4
112	4		3
113	3		3
114	2	FSL-5 Control CSCI Receive Data Monitor _	1
115	1	FSL-5 Monitor CSCI Receive Data Monitor _	0
116	12		61
117	11		60
118	10	FSL-5 Control CSCI Receive Data Monitor _	59
119	9	FSL-5 Monitor CSCI Receive Data Monitor _	58
120	8		57
121	7		56
122	6	FSL-5 Control CSCI Centering Monitor _	13
123	5	FSL-5 Monitor CSCI Centering Monitor _	13
124	4		12
125	3	FSL-5 Monitor CSCI Centering Monitor _	2
126	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
127	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
128	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
129	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
130	2	FSL-5 Control CSCI NLG WOW Error Monitor	1343
131	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1342
132	4		3
133	3	FSL-5 Monitor CSCI Centering Monitor _	2
134	2	FSL-5 Control CSCI NLG WOW Error Monitor	1
135	1	FSL-5 Monitor CSCI NLG WOW Error Monitor	1
136	8		24

137	7	23
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