



U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

ODI RESUME

Investigation: EA07-016

Prompted By: PE07-032

Date Opened: 11/16/2007

Dated Closed: 08/19/2009

Principal Investigator: Peter Kivett

Subject: Overheating Disc Brake Caliper

Manufacturer: Workhorse Custom Chassis

Products: 2000-2005 Workhorse Chassis Built with Bosh Brake Calipers

Population: 50,942

Problem Description: One or more brake calipers may drag, causing the brakes to overheat.

FAILURE REPORT SUMMARY

	ODI	Manufacturer	Total
Complaints:	191	102	191
Crashes/Fires:	0	0	0
Injury Incidents:	0	0	0
# Injuries:	0	0	0
Fatality Incidents:	0	0	0
# Fatalities:	0	0	0
Other:	0	1234	1234

Description of Other: Relevant warranty claims for fire, burn, smoke and drag.

Action: This investigation is closed. Workhorse has conducted a Safety Recall, 09V-110.

Engineer: Peter Kivett

Date: 08/19/2009

Div. Chief: Richard Boyd *RB*

Date: 08/19/2009

Office Dir.: Kathleen C. DeMeter

Date: 08/19/2009

Summary:

The EA was opened to gain a technical understanding of the causes for one or more disc brake calipers on a subject vehicle to suffer severe overheating. The overheating caused brake drag, melting ABS sensors, smoking, brake lining fires, and in some cases boiling brake fluid resulting in diminished stopping capability.

Based on testing, warranty and complaint data analysis, field trips and interviews with owners, mechanics and service managers, ODI believes the likely cause of the alleged defect is water swell of the phenolic caliper piston and subsequent failure of the piston to fully return after the pedal is released.

A technical report is attached with full details.

ENGINEERING ANALYSIS CLOSING REPORT

SUBJECT VEHICLES: 2000-05 Workhorse Custom Chassis W20 and W22 Vehicles

EA No.: 07-016

Date Opened: 16-Nov-07

Date Closed: 8/19/09

BASIS: This investigation was upgraded to an Engineering Analysis (EA07-016) as the result of Preliminary Evaluation (PE07-032), which was opened in June 2007. During the PE there was an increasing complaint rate and fieldwork was conducted by Bosch, Workhorse Custom Chassis (WCC), and Office of Defects Investigations (ODI) representatives. The complaints concerned overheating disc brakes at one or more wheel ends due to dragging brakes. The source of the dragging brakes was unknown.

THE ALLEGED DEFECT: After the brake pedal is released, the piston in the disc brake caliper can fail to retract, resulting in a partial brake application that causes the brake caliper to overheat. The phenomena may occur at one or more wheel ends. The overheating brake caliper can cause brake drag, melt ABS sensors, create smoke, cause a brake lining fire, and boil the brake fluid resulting in diminished stopping capability.

VEHICLE POPULATION: During the investigation it was determined that the appropriate population was the Workhorse W22 chassis. WCC sold 50,492 W22-chassis vehicles in the United States, as shown in Table 1 by model year of production.

Table 1 - Subject Vehicle Production Data

Model Year	Production
2001	1,427
2002	8,272
2003	12,003
2004	13,551
2005	7,656
2006	3,429
2007	2,375
2008	1,572
2009	207
Total	50,492

BACKGROUND: The subject vehicles were originally produced with a Robert Bosch LLC (Bosch) caliper model referred to as a ZOPS (Zero Offset Pin Slide). The ZOPS caliper was the subject of NHTSA ODI investigations PE02-046, EA02-034, EA02-035, and EA03-003, and recall Nos. 02V-243 (Western RV), 02V-278 (Monaco RV), 03V-062 (International), 03E-064 (Bosch), 04V-019 (Newmar RV), 04V-084 (Workhorse Custom Chassis), 04V-271 (Freightliner), and 04V-311 (Spartan RV). There were multiple root causes for these recalls, but the main issues were corrosion in the caliper-housing bore (creating an interference fit between the piston and the bore that caused the piston to fail to retract when the brake pedal was released) and excessive caliper slide resistance at the pins. The majority of the companies had an inspect, repair, replace as necessary remedy. Western and Spartan RV replaced the old calipers with the new model, called the Zero Offset Harmonized Truck (ZOH-T). Model Production of the ZOHT

model hydraulic disc brake calipers commenced in June 2002. The ZOHT model had several changes from the superseded ZOPS model. The ZOPS caliper, produced from 1998 to 2002, is an updated version of a similarly designed caliper that used a “railslide” sliding suspension system. Subject vehicles for the current investigation were determined by complaints which spanned both the ZOPS and ZOHT caliper populations.

DESCRIPTION OF COMPONENT/VEHICLE SYSTEM: The ZOHT brake assembly installed on the subject vehicles consists of five major components: the rotor, disc brake pads, caliper assembly, (caliper) pin slide suspension, and anchor plate. The model brake caliper utilizes a hydraulic two-piston sliding-caliper design intended for use on front and rear axles of medium-duty trucks. The caliper is a one-piece casting with two bores for two pistons aligned with the inner rotor surface. The caliper housing spans the rotor then splits into three “fingers” that maintain alignment between the brake pad and the outer rotor surface. A caliper is shown on a front axle in Figure 1. A piston, piston-hydraulic seal, and piston environmental boot are installed in each of the two caliper-piston bores. The pistons are made of a phenolic material that is ground to tolerance diameter and machined with a shallow circumferential groove near the top of the piston to provide a seat for the environmental boot. The caliper housing has an internal passageway allowing for the flow of brake fluid from the master cylinder to the pistons. The brake pads ride on the anchor plate abutments, which are protected with stainless steel slippers.

The caliper assembly attaches to and slides on two pins bolted to the anchor plate. The pins are enclosed in an environmental bellows allowing the caliper to “float” or “slide” laterally on the lubricated pins isolated from the environment. This sliding feature is intended to ensure equal distribution of forces on the inner and outer brake linings. The inner lining force is from the pistons and the outer lining force is the reactionary force through the housing of the sliding/floating caliper, as shown in Figure 2. It also allows both brake linings to retract from the rotor when the hydraulic pressure is released. This design avoids the expense of a larger housing that contains four pistons, two at each brake lining. The ZOPS caliper used a similar design. The predecessor to the ZOPS, called railslide, transmitted the reactionary force by the caliper sliding in an external V-shaped groove that was exposed to the environment. The change to the environmentally sealed pins was made to reduce lining wear (reduced friction in the slide

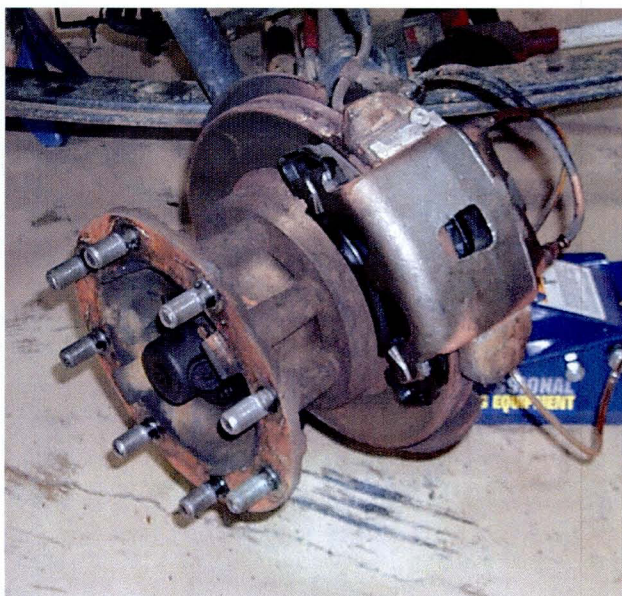


Figure 1 – Front Brake Caliper and Rotor

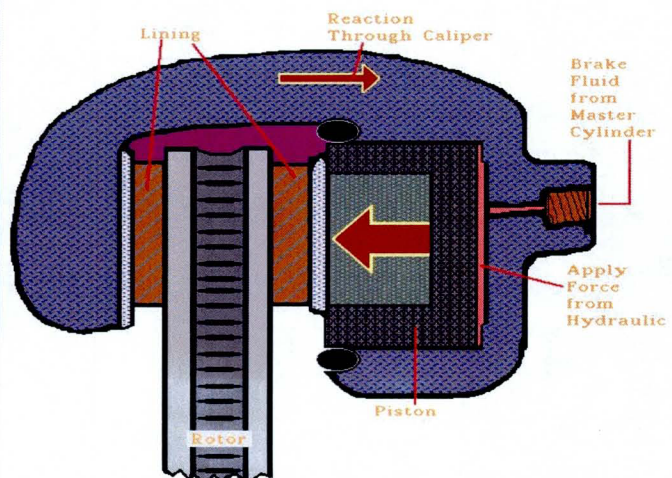


Figure 2 - Brake Clamps Both Sides of the Rotor by Reaction Force Through the Caliper

mechanism) and improve fuel mileage.

The ZOPS/ZOHT anchor plate is mounted to the steering knuckle flange on the front axles and to the brake-mounting flange on the rear axles. The rotor is bolted to the wheel hub assembly. Cooling fins allow air to flow between the inner and outer rotor surfaces. The antilock tone wheel is cast on the inboard side of the rotor. The dual hydraulic system is split between the front axle and rear axles for partial failure protection. A brake application is transferred from the brake pedal to a pushrod that rotates a bellcrank pivot, as shown in Figure 3, transferring pressure to the sideways mounted Hydro-Max booster and the master cylinder. The vehicles with these brake calipers are used on a variety of applications such as school buses, transit busses, straight trucks, recreational vehicles (RVs), ambulances, and emergency vehicles. The bell crank grease fitting is an item of interest and will be discussed later in this report.

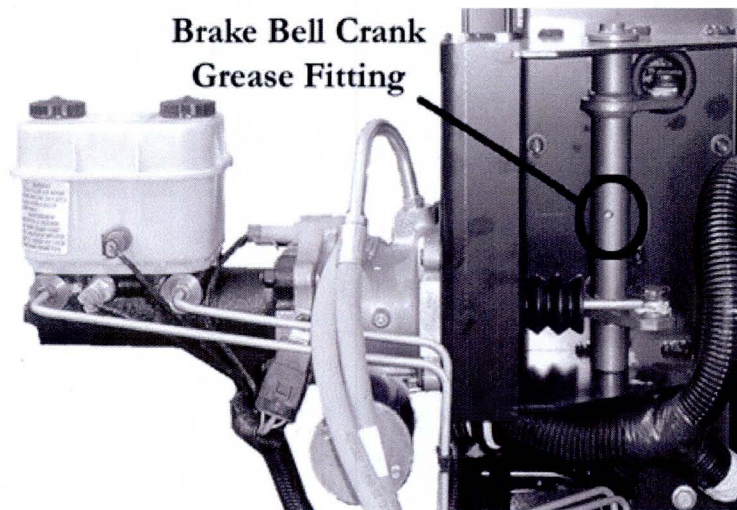


Figure 3 – The Bellcrank Pivot Changes Longitudinal Brake Pedal Push Rod Action to a Lateral Direction for the Hydro-Max Booster and Master Cylinder

CORRESPONDENCE: Table 1 lists the correspondence between WCC and NHTSA.

Table 2 – Correspondence with Manufacturer

NHTSA to MFR	MFR to NHTSA	NHTSA to MFR Supplement	Confidentiality		
			Date of Request	Date of NCC Response	Items Confidential
5-Jul-07	20-Sep-07		8-Oct-07	8-Jan-08	App. 1,2,5,6, & 8
			8-Jul-08	19-Nov-08	
	24-Nov-08		24-Nov-08	10-Dec-08	App. 3 & 4

VEHICLE INSPECTIONS: During this investigation (including PE07-032), field inspections were conducted to examine complaint vehicles in order to gain an understanding of the consumer complaints and identify underlying conditions, and determine if the complaint could be duplicated on the complaint vehicles and identify the root cause. Neither ODI nor the Vehicle Research and Test Center (VRTC), NHTSA's in-house test laboratory, attended the Florida and Michigan inspections in October 2007. The results of these inspections were inconclusive and ODI decided that, along with VRTC, they would attend future inspections. The Texas inspection was then arranged. VRTC attended five and ODI three of the remaining five field inspections. These field inspections were conducted at the locations, dates, and with representatives from the groups listed below:

Green Acres, Florida	October 11, 2007	WCC and Bosch
Saginaw, Michigan	October 19, 2007	WCC and Bosch
Pasadena, Texas ¹	November 13-14, 2007	WCC, Bosch, ODI, VRTC
Sunbury, Ohio ²	December 13, 2007	VRTC
Hammond, Louisiana ³	January 8, 2008	WCC, Bosch, ODI, VRTC
Baton Rouge, Louisiana	January 9, 2008	WCC, Bosch, ODI, VRTC
Plant City, Florida ⁴	March 10-14, 2008	WCC, Bosch, VRTC

Table 3 (page 7) provides a summary of the results of the field inspections conducted in Pasadena, Texas; Sunbury, Ohio; Hammond, Louisiana; and Plant City, Florida. The table includes data obtained for each wheel end through interviews, inspection, and test drives, as well as a narrative comment column. The Baton Rouge Louisiana vehicle turned out to be a complaint for engine misfire. Dealership personnel test drove the vehicle and identified brake drag and notified WCC. The "team" was unable to replicate the drag.

During the field inspection in Pasadena, TX, it was found that after a test drive, it was difficult to rotate the wheels after the vehicle was raised off the ground. As a result, to facilitate future testing a crossbar was subsequently designed at the VRTC test center and then tested at a local (Ohio) dealership with a beam-type torque wrench to quantify the drag on a raised wheel before and after driving the vehicle, as shown in Figure 4. The Ohio exemplar vehicle required approximately 10 ft-lbs to rotate a front wheel and 45 ft-lbs to rotate a rear wheel. This device helped the investigation team to quantify the amount of drag torque at each wheel and isolate the failed brake(s). A memorandum trip report on this field trip is available at the ODI website. A summary of the results of several inspections is shown in Table 3.

During the field inspection in Hammond, Louisiana, WCC, Bosch, ODI and VRTC personnel inspected a vehicle, the owner of which reported brake drag. After the initial inspection and test drive, the service technician was asked how he diagnosed an intermittently dragging ZOHT brake. The technician demonstrated a driving procedure that triggered the brake drag at multiple wheel ends as shown in orange in Table 3. The Workhorse/Bosch/VRTC team then determined that the brake drag was caused by the piston not retracting within the caliper-housing bore. No "external" influences were observed, such as ABS activity, or brake line pressure due to a collapsed line.

¹ "Workhorse-Bosch Trip Report" (listed as [INME-EA07016-27535.pdf](#))

² "Trip Report to Sunbury Ohio (Greer RV Dealership)" (listed as [INOT-EA07016-35283.pdf](#))

³ "Hammond, LA Workhorse-Bosch Trip Report" (listed as [INME-EA07016-33584.pdf](#))

⁴ "Plant City, FL Workhorse-Bosch Trip Report" (listed as [INME-EA07016-33583.pdf](#))



Figure 4 - Wheel Torque Crossbar and Beam-Type Torque Wrench to Measure Normal and Abnormal Drag on Rotating a Raised Wheel

During the field inspection in Plant City, Florida, WCC, Bosch, and VRTC examined a complaint 2004 Sea Breeze LX motorhome with 9,155 miles shown on the odometer. The vehicle's owner had reported a dragging brake to WCC. Prior to any road tests, a dealer technician repaired the leaking left front wheel bearing seal that had previously failed due to an overheated caliper the last time the vehicle was driven. For testing purposes, the vehicle was equipped with, among other items, four temperature and four pressure transducers, one at each wheel end, which were monitored and recorded during test drives. On the third test drive, when the vehicle encountered stop-and-go driving through a commercial area, the rear brake rotor temperatures increased to over 1,000°F while the front rotors measured approximately 300°F. There was no indication of the increased rotor temperatures to the driver; he did not feel the increased brake drag and the vehicle did not shudder. The temperatures of the rear rotors decreased shortly thereafter. The data collected during this event was later studied at the dealership and **no brake pressures were present during the brake drag event,** an indication that the problem was internal to the caliper. Bosch later measured the piston diameters and found them to exceed the factory specifications.

The orange boxes in Table 3 indicate an apparent abnormal result. The brake drag problems were found to be intermittently present at a wheel end, move to another wheel end, or be present at multiple wheel ends. Internal corrosion, slide pin problems, and trapped brake line pressures were eliminated as possible root causes for the intermittently dragging brakes as a result of physical inspections conducted during these field trips. From this information, VRTC also excluded as unlikely the bellcrank as the cause of the alleged defect. A defective bellcrank would repeatedly effect braking at all wheel ends. That was not the case here. Further a visual inspection of the bellcrank showed that it was operating properly.

Table 3 – Summary of Fieldwork

Location	Event	Left Front	Right Front	Left Rear	Right Rear	Comments
Pasadena, Texas WCC Located Complaint Vehicle	Owner Interview	na	na	na	overheated on last drive	three months ago, owner had vehicle in storage, drove to gas station, smelled hot brakes - RR too hot to touch, pedal to floor while driving back to storage
	Inspection	na	na	na	na	bellcrank pivot without Zerk fitting, but free to rotate, RR ABS sensor melted, ABS light on
	Owner Drove to Dealership	hard to turn	hard to turn	hard to turn	hard to turn	30-minute drive to dealership, front wheels turned with medium force, rear wheels required much more than expected, right rear caliper squirted fluid when bleeder was opened, the others dribbled, after the brakes cooled the wheels seemed easier to turn
		na	na	na	na	
	Day #1 Test Drive #1	180°F	185°F	185°F	305°F	intermediate stop check temperatures during 15 minute-drive, RR hotter than expected
		370°F	265°F	450°F	300°F	after 15-minute drive in stop-and-go area vehicle would not roll forward when brakes were released from stop, the wheels had more drag than expected when turned by hand, RR bleeder again squirted more fluid than others
		hard to turn	hard to turn	hard to turn	hard to turn	
	Day #1 Test Drive #2	341°F	345°F	341°F	403°F	15-minute aggressive stop-and-go drive in commercial area, hard to turn wheels, minimal fluid out of all bleeders, theory on the RR running hotter: hydraulic seal could be damaged from the original overheating, the square seal distorts when the piston is actuated and creates the returning force on the piston
		hard to turn	hard to turn	hard to turn	hard to turn	
	Day #2 Test Drive #1	137°F	130°F	134°F	179°F	30-minute drive on freeway, then stopped to refuel and measured brake rotor temperatures
		na	na	na	na	
Sunbury, OH Dealership Exemplar Vehicle	Test Drive #1	300°F	280°F	119°F	134°F	exemplar vehicle was driven to try the newly fabricated cross bar for determining wheel rotational torque, vehicle driven 7 miles with light braking, consider temperatures and wheel rotational torques normal
		8 ft-lb	5 ft-lb	40 ft-lb	43 ft-lb	
	Test Drive #2	290°F	241°F	230°F	240°F	driven shorter route, but with more braking, all normal
		5 ft-lb	5 ft-lb	20 ft-lb	20 ft-lb	
Hammond, Louisiana WCC Located Complaint Vehicle	Technician Interview	na	na	na	na	owner reported 30 days that ago while in stop-and-go driving, vehicle felt like it was "holding back", ABS light illuminated, and noticed a brake smell, a walk around found RR wheel hottest, LR also hot, fronts warm, vehicle then parked at dealership
	Inspection	na	na	na	na	bellcrank pivot without Zerk fitting, but free to rotate, RR rotor darker than others, both rears some lining transfer, ABS codes for RR sensor, excess isolation time
	Test Drive #1	617°F	702°F	570°F	423°F	after 20 minute stop-and-go driving (accel to second gear and then brake), vehicle would not roll forward when brake pedal released, hot brake smell, at the shop the brake bleeder valves were opened and found no trapped pressure
		115 ft-lb	120 ft-lb	90 ft-lb	100 ft-lb	
	Test Drive #2	na	55 ft-lb	na	55 ft-lb	after short cool down, wheel rotation torques were rechecked
		665°F	757°F	567°F	438°F	17 minute stop-and-go driving, same as before, vehicle would not roll forward when the brake pedal was released, hot brake smell, no trapped pressure found when bleeders opened
		145 ft-lb	95 ft-lb	142 ft-lb	65 ft-lb	
	Test Drive #3	3 ft-lb	15 ft-lb	25 ft-lb	45 ft-lb	after short cool down, wheel rotation torques were rechecked
		463°F	488°F	492°F	413°F	17 minute stop-and-go driving, following the "Hilton Procedure", LF wheel bearing seal failed dumping hub oil on the brake rotor, vehicle was driven back to the dealership
		35 ft-lb	30 ft-lb	95 ft-lb	70 ft-lb	
	Test Drive #4	627°F	706°F	725°F	523°F	31 minute Hilton Procedure, vehicle would not roll forward when the brake pedal was released, no trapped pressure found when bleeders opened, slide pin bolts removed and caliper was still clamped onto rotor - problem is internal to the caliper
		120 ft-lb	170 ft-lb	250+ ft-lb	80 ft-lb	
	Test Drive #5	680°F	688°F	680°F	581°F	24 minutes Hilton Procedure to heat the brakes, first indication of brake drag
		329°F	380°F	568°F	354°F	15 minutes steady driving through rural area, most temperatures dropping
		306°F	305°F	448°F	319°F	14 minutes driving rural area back to dealership
Plant City, Florida WCC Located Complaint Vehicle	PreInspection	overheated on last drive	replaced in 2006	na	na	LF wheel bearing cap plug melted and wheel-bearing seal leaked from overheating - repaired the day before team arrived
	Inspection	20 ft-lb	11 ft-lb	20 ft-lb	24 ft-lb	bellcrank pivot without Zerk, but free to rotate, cold torques during initial inspection, found evidence the rear brakes had been overheated, ABS codes LF and RR
	Day #1 Test Drive #1	na	179°F	na	na	RV driven for 44 miles, side-to-side and front-to-rear variations in temperatures, but all in expected range
		20 ft-lb	12 ft-lb	88 ft-lb	106 ft-lb	
	Day #2 Test Drive #1	220°F	219°F	339°F	314°F	after 53 miles of freeway driving toward Kissimmee State Park, while braking, the vehicle pulled forcefully to the right
		na	na	na	na	
	Day #2 Test Drive #2	~300°F	~300°F	1000+°F	1000+°F	while driving 29 miles, including Lake Wales stop-and-go driving, the driver was unaware of brake problem with no engine drag or shuddering, then instrumentation showed both rears freed and temperatures dropped, no brake lines were pressurized during the high temperature event
		na	na	na	na	
	Day #2 Test Drive #3	na	na	na	na	11 miles later at the State Park, the wheel rotation torque was measured, the rear torques were discounted due to rear jack problems caused the measurements to be taken while the vehicle was dropping to the ground
		34 ft-lb	18 ft-lb	63 ft-lb	16 ft-lb	
	Day #2 Test Drive #4	na	na	na	na	after a two-hour long cool down, the vehicle was driven 47 miles back to the dealership, the steady driving produced normal temperatures, at the dealership the vehicle was raised and the torques were measured and found to be normal
		26 ft-lb	14 ft-lb	55 ft-lb	58 ft-lb	
	Day #3 Test Drive #1	na	na	na	na	after a 58 mile drive to Kissimmee State Park - all temps normal all torques normal, the vehicle was not pushed to overheating with the Hilton Procedure so that the parts could be later disassembled and examined at Bosch HQ, pistons were later found to be out of specification with larger than allowed diameters
		33 ft-lb	24 ft-lb	64 ft-lb	46 ft-lb	
	Day #3 Test Drive #2	na	na	na	na	after a 67 mile drive back to the dealership - some brake pull (to the right) was noted when stopping, but all torques were normal

= apparent abnormal result

= expected value from exemplar vehicle

VRTC-TESTING: Phenolic pistons in calipers returned from the field were found to be oversized. Factory records indicated the pistons had originally been manufactured within the required specifications. One theory for the identified out-of-spec condition was water absorption by the phenolic piston on these lightly used RVs. VRTC focused their testing efforts to determine the extent of piston diameter increase due to “water swell.” A test was designed to attempt to accelerate the phenolic piston swell observed to occur over a two or three year period of “low usage.” A steadily increasing diameter during bench testing would confirm the water swell theory and allow appropriate remedies to be evaluated by the manufacturers. Each piston was measured at 12 different diameter positions. The data sheet, with 12 measurements, was assembled into a mean-box-plot icon, as shown in Figure 5. This testing was designed to accelerate water absorption in the phenolic matrix by exposing the pistons to a pressure range of +/-7 psig, a temperature range of 40 to 170°F, and a humidity of between 50 and 100%. The ZOHT pistons were compared to peer phenolic and steel pistons. All of the phenolic pistons, including the ZOHT pistons, continued to grow at a steady rate throughout the entire test period, as shown in Figure 6. If these pistons (now oversized due to test induced “water swell”) were installed in a caliper on a vehicle that was driven in “heavy traffic” stop-and-go driving, the pistons likely would not retract after the driver released the brake pedal due to inadequate clearance between the (oversized) piston and the caliper bore. The steel pistons varied little, as shown in Figure 7. The piston weights showed the same trend, as can be seen in more detail in the PowerPoint⁵ summary of this testing located at the ODI website.

⁵ April 30, 2009 Summary Review PowerPoint titled, “*Accelerated Test Series to Determine the Extent of Water Swell in Phenolic Pistons*” (listed as [INRP-EA07016-35282.pdf](#))

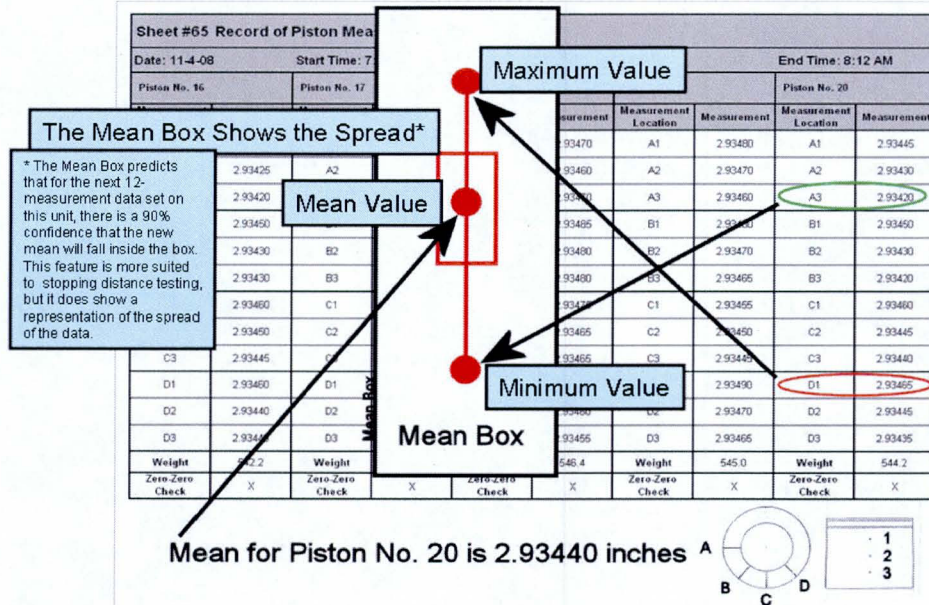


Figure 5 – The Mean-Box Plot Icon Shows the Max, Min, and Mean of the 12 Diameters Measured on Each Piston

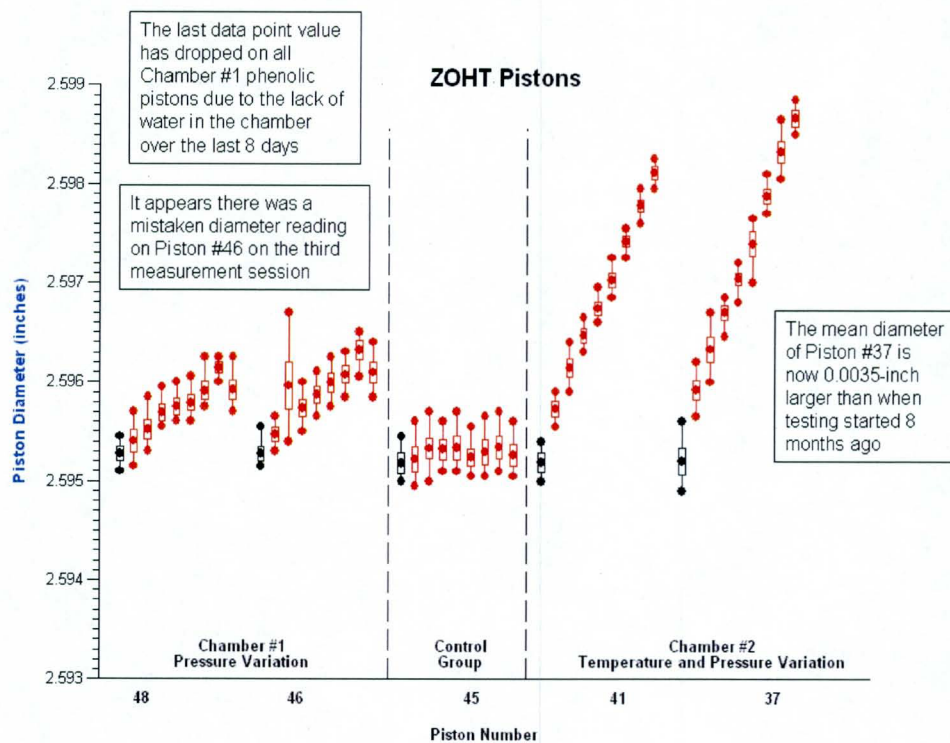


Figure 6 – The ZOHT Pistons Increased in Diameter, Especially in Chamber #2 with the Temperature Cycles

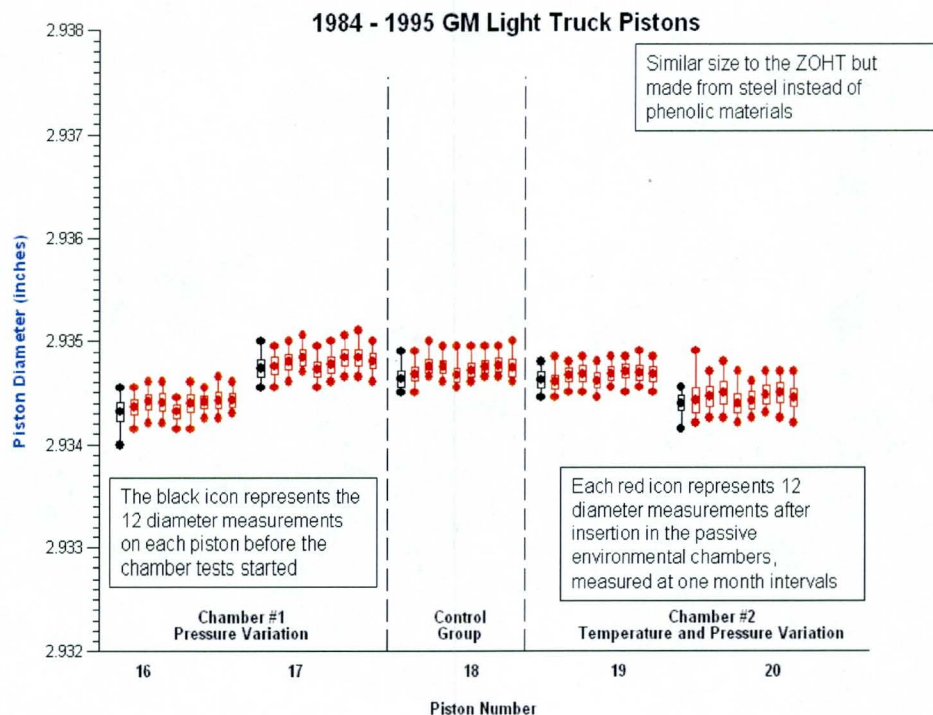


Figure 7 – The Steel Pistons Remained Stable in Diameter and Weight

WARRANTY/COMPLAINT/VOQ DATA ANALYSIS: ODI/VRTC collected and analyzed WCC warranty and complaint data and ODI Vehicle Owners Questionnaire (VOQ) data. Upon the opening of this Engineering Analysis, ODI was aware of 651 non-duplicative complaints from all sources (including 20 VOQs). The EA Information Request (IR) data was updated by WCC on November 24, 2008. In that update, WCC reported 8,482 warranty claims (consisting of 11,175 individual entries), and in February 2009 reported an updated 493 complaints. At that time ODI had received 191 VOQs. ODI reviewed the claims and culled them to 1,234 relevant warranty claims, 102 relevant Workhorse complaints and 191 VOQ's as shown in Table 4. For purposes of this investigation, complaints were deemed relevant if a Bosch caliper was replaced due to seized/hot brakes or if the consumer or technician reported a symptom which was traced to the brake pedal not returning after a brake application.

Table 4 – Number of Reports to ODI

Problem Experience	EA Open		EA Close	
	ODI	MFR	ODI	MFR
Owner Reports	20	639	191	102
Field Reports	0	0	0	0
Warranty Claims	NA	3,782	NA	1,234
Crash Incidents	0	0	0	0
Injuries	0	0	0	0
Fatal Incidents	0	0	0	0

Warranty Claims: Each WCC chassis has a 3-year/36,000-mile warranty. In November 2008, WCC supplied ODI with 8,482 warranty claims consisting of 11,175 unique warranty work items in an Excel spreadsheet. (Both the ZOPS and the ZOHT calipers used the problematic phenolic piston and it was deemed relevant to examine all the data.) Claims made on each ZOPS-equipped vehicle prior to the recall remedy date of each individual vehicle were removed, as they could have been influenced by the problems addressed in the first recall. All duplicate mileage entries were reduced to one listing retaining the text corresponding to the most severe event. This resulted in a total of 1,234 “relevant” warranty claims. Specific to the Bosch brake caliper were 752 claims and for the WCC bellcrank, 482 claims, as determined by VRTC. The claims were attributed to the following root causes based upon the described circumstantial evidence gleaned from the invoices:

- **Bosch seized brakes for ZOPS/ZOHT piston:** 752 warranty claims - These entries contained warranty text that indicated the caliper was replaced due to seized/hot brakes.
- **WCC bellcrank pivot repair:** 482 warranty claims - These entries contained warranty text that indicated the consumer or technician reported the bellcrank pivot to be sticking, brake pedal was slow to return, brake lights were continuously illuminated, cruise control inoperative, etc.

Keyword searches for “Fire,” “Burn,” “Smoke,” and “Drag” (FBSD) in order of severity with “fire” being the most severe, were conducted on the 1,234 relevant entries in the warranty database. Only the most severe word was counted if more than one appeared in a single entry.

Keyword reviews of the 752 Workhorse warranty claims concerning the internal Bosch caliper problems searched the unique text in the three comment fields and a unique repair code for caliper replacement. The FBSD keyword search was run on the 752 relevant Bosch seized brake claims, resulting in locating fire (4 complaints), burn (121 complaints), smoke (57 complaints), and drag (504 complaints) keywords (totaling 686 complaints.) The remaining 66 claims, while not using the indicated key words, were specific enough in the summaries that they were deemed relevant.

The 482 bellcrank claims are a subset of 797 total warranty claims that presumably were related to the bellcrank. After interviews with the dealership service managers and technicians and further review of the repair orders, 315 repair orders were eliminated as bellcrank repairs because they were considered to be misclassified. This left 482 claims as relevant.

The FBSD keyword search of the 482 identified WCC bellcrank pivot repairs located fire (0), burn (9), smoke (3), and drag (311) allegations (total 323). The remaining 159 claims deemed relevant did not contain any of these keywords.

A separate keyword search for boiled brake fluid was conducted on the 1,234 relevant entries and showed a difference in the severity level, returning 46 alleged brake fluid boil events due to the Bosch stuck piston and 8 alleged boil events due to WCC bellcrank pivot. The warranty data set was the only database with sufficient information (replaced parts, technician text, and owner comments) that would allow a detailed analysis to determine whether a claim pertained to boiling brake fluid. For more information on this data (and data on the WCC Complaints and ODI VOQs), see the February 24, 2009 presentation⁶.

⁶ February 24, 2009 PowerPoint titled, “VRTC Review and Testing of Overheating Bosch Brakes on Workhorse RV Chassis” (listed as INIB-EA07-016-2940.pdf)

WORKHORSE COMPLAINTS: In February 2009, WCC submitted 493 complaints on vehicles equipped with ZOPS and ZOHT calipers. (Of the 493 complaints, 459 had been previously submitted during the Preliminary Evaluation.) Claims made on each vehicle prior to the ZOPS recall date of each vehicle were removed. All duplicate mileage entries were reduced to only one listing with text corresponding to the most severe event. This analysis reduced the 493 WCC complaints to 102 relevant claims. For the 102 complaints, a keyword search was performed for fire (1 complaint), burn (20 complaints), smoke (5 complaints), and drag (61 complaints) keywords (totaling 87 complaints). Another keyword search was conducted for “boiled” brake fluid using keywords floor, boil, spongy, soft, mushy, no brakes, and lost brakes. This keyword search review located 11 alleged boiled brake fluid reports.

ODI VEHICLE OWNER’S QUESTIONNAIRE (VOQ) ANALYSIS: ODI received 191 VOQ’s that reported allegations that were deemed relevant to this matter. A keyword search was performed for FBSD and separately boiled brake fluid. This complaint analysis showed: fire (2 complaints), burn (16 complaints), smoke (6 complaints), drag (30 complaints) and boiled brake fluid (56 complaints). Insufficient technical data existed to determine the exact cause for these boiling complaints.

WCC BELLCRANK TESTING: During PE07-032, ODI became aware of complaints that seemingly indicated a compromising condition preventing the full return of the bellcrank linkage which connects the brake pedal through the firewall to the master cylinder. Data trends showed a decline of related “drag” complaints after the factory began installing a “Zerk fitting” (grease fitting, see figure 3) onto the bell crank in June 2004. The Zerk fitting allowed for lubrication of the bellcrank to prevent the unit from sticking and causing dragging brakes. Although ODI initially focused on bellcrank-related brake drag, testing by WCC with an artificial stop on the bellcrank preventing full return showed that after a period of driving, the brake pressures would increase and then overpower the engine and cause the vehicle to stop before the brake fluid could boil. Further, few complaints of disabled vehicles were noted during ODI’s and VRTC’s assessments of complaints and warranty claims—the dominant issue was brake drag. Additionally, the field inspections (referenced on page 5) clearly identified an internal problem with the caliper.

During the last data analysis in November 2008, the bellcrank again was noted as a possible source of brake drag within the 482 warranty claims. Some claims indicated that owners were having problems with the brake pedal not fully returning when released, the brake lights staying illuminated after release of the brake pedal, inoperative cruise control systems, and various degrees of brake drag (all four wheels). Eight of the 482 claims alleged brake fluid boil. These 482 complaints led to the intensive review of the warranty invoices (see page 11), and WCC conducted a new series of tests with artificially induced drag to varying degrees at the bellcrank pivot.

In the most severe test, WCC tested a vehicle with a 35 mph stop-pause-and-go cycle with the bellcrank drag set at 40 in-lbs or almost 8 times the rotational drag found during the standard GM salt test.⁷ The amount of drag induced during this test is far beyond what WCC would expect to see in the field. During stop-pause-and-go cycling, the brake fluid temperature climbed from ambient of approximately 70°F to 135°F. During the drive back to the shop at approximately 50 mph, the driver reported that the RV strained in 4th gear (could not shift normally into 5th or 6th gear) and it was difficult to maintain 50 mph, indicating brake drag.

⁷ The standard salt spray test for the pivot shaft is 168 hours (Par coating specification is to “GM4345-M-90 168/96,” which means passivated or conversion coated to withstand 168 h neutral spray without evidence of base metal corrosion and 96 h neutral salt spray to zinc corrosion products.)

When the vehicle was parked in the shop, the brake fluid temperature was approximately 210°F and after sitting for a 10-minute stationary heat soak the fluid temperature peaked at 265°F. New brake fluid boils at approximately 425°F, and used, water-saturated brake fluid boils at approximately 285°F. Thus, this severe series of tests indicate that a stuck bellcrank can cause brake drag but likely does not cause brake fluid boil. Based on this test, the prior testing by WCC described above, and the relatively few reports of disabled vehicles, ODI concluded that a stuck bellcrank likely is not the cause of the alleged defect or the eight (8) allegations of brake fluid boil. A summary of the test is available at the public website for this investigation under “Bellcrank Testing.”

FAILURE MODE: The water swell of the phenolic piston occurs when a vehicle is operated only occasionally and driven in a “stop-and-go” environment, such as heavy traffic in a city. In these conditions, the phenolic pistons absorb water and their diameter increases and creates an inadequate clearance between the phenolic piston and caliper bore only during stop-and-go driving, preventing the piston from retracting after a brake application until the brakes cool. Typically, the heat of routine driving removes moisture that may have been absorbed by the phenolic piston (other medium duty trucks equipped with this brake system typically are driven daily). However the RV vehicles typically sit for months at a time between uses. As a result, the pistons on the subject vehicles retain moisture and eventually grow large enough to interfere with the bore. Generally, the wheel end equipped with a caliper piston experiencing sufficient water swell will experience brake drag, smoking, melting of the ABS sensor, a possible wheel end fire and potential brake fluid boil (Figure 8). The final and most severe failure mode is when the brake fluid boils and the brake pedal goes “to the floor.” ODI has conducted owner interviews during which the consumers stated that when the brake pedal went to the floor they could not stop the vehicle. Some reported that they ran through stop signs and red lights. In some cases, consumers stated that they had to make aggressive steering maneuvers to avoid pedestrians and other vehicles while trying to stop their vehicle.

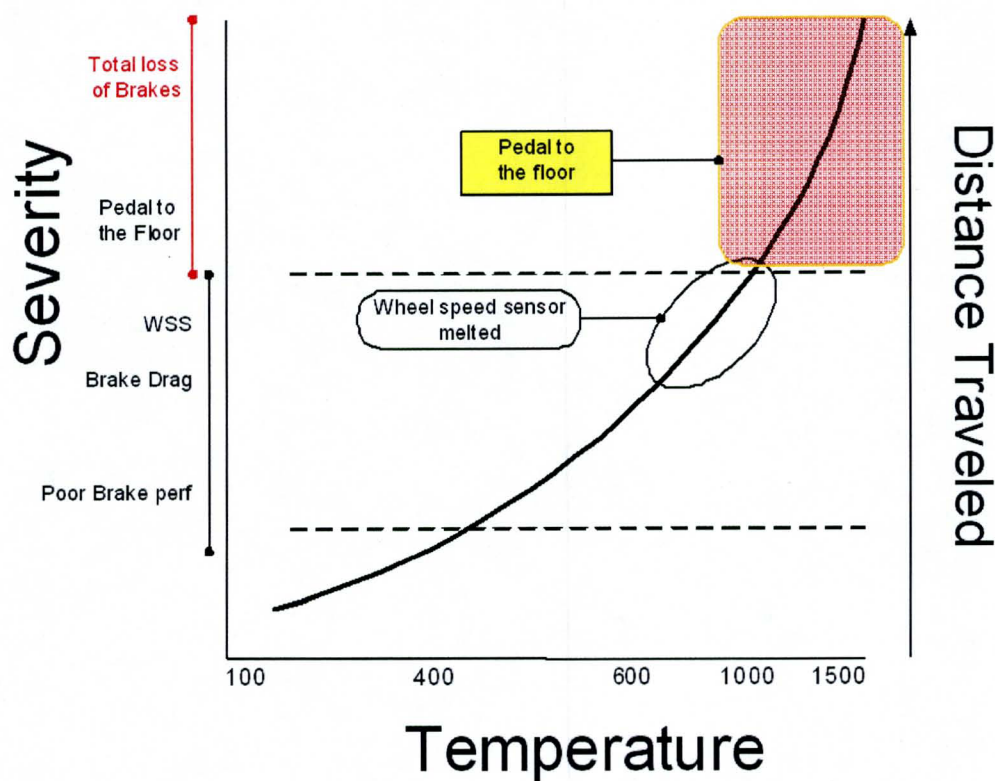


Figure 8 - Failure Mode Progression

OBSERVATIONS: The following symptoms have been noted:

1. The driver may become aware of a “drag” on the vehicle driveline that requires additional throttle application in order to maintain vehicle speed;
2. The vehicle may pull in one direction due to a seizing front left or right caliper;
3. The ABS light may come on due to melting from the excessively high temperature;
4. Vehicle occupants may smell burning and/or observe smoke from one or more wheel ends;
5. A small brake lining fire at a wheel end may be observed by people outside of the vehicle;
6. The brake pedal may get mushy or have an extended stroke.

WORKHORSE’S EVALUATION OF THE ALLEGED DEFECT: On April 1, 2009, Navistar, Inc. (parent company for WCC) initiated a safety recall (NHTSA Recall No. 09V-110). Navistar stated, “Certain RV applications equipped with axles that include Bosch ZOPS or Bosch ZOHT pin slide hydraulic disc brakes when combined with occasional or seasonal vehicle operation may experience calipers sticking in the applied position. This can result in abnormal heat generation at the wheel end causing brake drag. Although the driver would normally have warning of the brake drag – if undetected by the driver, the temperature increase at the wheel end can eventually lead to soft pedal conditions due to brake fluid boil and possible extended stopping distances.”

ODI ANALYSIS: ODI’s prior investigations, (EA02-034 and EA02-035) discovered failures of the environmental seal and/or slide pins, either of which could result in a partially applied (dragging) brake caliper. Under the current investigation, during field inspections (with vehicle testing) the defect was found to be located internal to the caliper. During one field inspection, the rear brake temperatures were found to temporarily spike to over 1000°F during stop-and-go

driving in a commercial strip area. During this runaway of brake temperatures the rear brake line pressures were found to be zero, further verifying that the problem was internal to the caliper.

Bench testing at VRTC verified that the phenolic pistons could absorb moisture, swell in diameter and create an interference fit in the caliper bore during the heat shock of stop-and-go driving. The ZOHT pistons grew up to 0.0035-in in diameter during the eight month accelerated testing, similar to pistons that had been sitting unused for three years. According to relevant WCC warranty and complaint data and ODI's VOQ data, this interference can result in fire, burn, smoke, brake drag and boiling brake fluid. The first three conditions can result in decreased braking performance and the last condition (boiling brake fluid), a total loss of braking on a subject vehicle.

Very serve testing conducted by WCC with the bellcrank drag set at 40 in-lbs (8 times higher than the standard GM salt test) resulted in brake drag but did not result in boiling brake fluid. While ODI is aware of 8 warranty claims for boiling brake fluid related to a stuck bell crank, ODI believes that based on VRTC and WCC testing; warranty and complaint data analysis; five field trips; and interviews with owners, mechanics and service managers; the likely cause of the alleged defect is water swell of the Phenolic caliper piston and subsequent failure of the piston to fully return after the brake pedal is released, resulting in severe overheating, dragging and brake fluid boil at one or more wheel ends.

REASON FOR CLOSING: Based on WCC's decision to conduct a safety recall (09V-110), this investigation is closed.

Peter Kivett



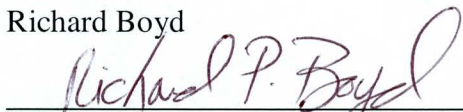
Safety Defects Engineer

8-14-09

Date

I Concur:

Richard Boyd

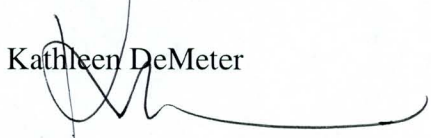


Chief, Medium & Heavy Duty
Vehicle Division

8/14/09

Date

Kathleen DeMeter



Director, Office of Defects Investigation

8-17-09

Date