# Memorandum

U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

**Vehicle Research and Test Center** **P.O. Box B37
East Liberty, Ohio 43319
(937) 666-4511**

EA07-016

Subject: FINAL REPORT: "Plant City Trip Report"

Date: JUN 20 2008

From: Michael W. Monk
Director, Vehicle Research and Test Center

Reply to Attn. Of: NVS-310

To: Kathleen DeMeter
Director, Office of Defects Investigation

NVS-210

Attached are four (4) copies of the subject report. This completes the requirements for this program.

Attachment:
Final Report

#

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# Plant City, FL Workhorse-Bosch Trip Report

**Date**: March 10, 2008 through March 14, 2008

**Destination:** Bill Heard Chevrolet
2002 North Frontage Road
Plant City, FL 33563

**Participants:** Dave Smith, Engineering Manager of Foundation Brakes (Bosch)
Carl Doolin, Senior Engineer Automotive Proving Grounds (Bosch)
Hennie van Niekerk, Director of Engineering Services (Workhorse Custom Chassis)
Mike Fanelli, Technician and Motorhome Specialist (Bill Heard Chevrolet)
Dan Pearse, Vehicle Safety Engineer (Vehicle Research and Test Center-DA Group)

**Purpose:** To examine a complaint vehicle that had experienced brake drag and hot brakes at multiple wheel-ends with representatives of the chassis and brake manufacturers.

**Background:** The complaint vehicle was a 2004 Sea Breeze LX motorhome built by National RV Inc. As shown on the data plate in Figure 1 in the Appendix, the vehicle was manufactured in November 2003 with Vehicle Identification No. 5B4MP67G243379581. The odometer listed 9,155 miles. The engine was a GM Vortec 8100. The Workhorse Vehicle and Service Information, supplied by the Workhorse representative, listed the Model No. as P32022, the wheelbase at 208 in, the GVWR at 22,000 lb, the GVWRF at 8,000 lb, the GVWRR at 15,000 lb, and the warranty start date was 01/28/2004. The vehicle was equipped with 22.5 inch wheels and 66-mm diameter piston calipers on the front and rear axles. The brake linings were OEM and the brakes on the front axle had been previously serviced as noted below. The ABS EHCU is model 410 made by TRW. The vehicle is shown in Figures 2 through 4. A summary of the warranty repairs performed on this vehicle is shown below.

| | | |
|---|---|---|
| 10/28/2003 | 1 mi | pre-delivery inspection |
| 07/01/2005 | 4,112 mi | right front wheel leaking oil and both front oil caps distorted, turn front rotors, replace right inner seal and both caps |
| 02/17/2006 | 7,605 mi | right front wheel seal leaking, replace seal and cap |
| 02/17/2006 | 7,605 mi | install new serpentine belt (chirping) |
| 02/17/2006 | 7,605 mi | reprogram instrument cluster recall 50402-C |
| 02/22/2006 | 7,803 mi | right front caliper sticking, replace right front caliper and rotor |
| 02/08/2008 | 9,121 mi | install the fuel-rail-damper clip, campaign 60601-C |
| 02/26/2008 | 9,155 mi | brakes were getting hot and dragging during a short drive, then released after cooling |

**Owner Interview:** The owners were interviewed at their home. They reported that they take short trips four to seven times per year, depending upon how good the fishing is at Kissimmee State Park. They drive the motorhome approximately every two months. They have a trip planned to North Carolina in June or July. The only long trip they have taken so far was to Washington DC two years ago, and during that trip, the hub site glass for the oil level on the right front hub "burnt out." The motorhome was not "going normally," and when he applied the brakes the vehicle pulled severely to the right. The rear brakes were warm, but normal. The brakes do not heat up every time he drives the vehicle. Sometimes the steering wheel shakes like a tire could come apart, and sometimes the entire vehicle shakes. They stop and he can smell the hot brakes.

They have owned six motorhomes and have not had a problem like this before. They do not tow anything with the motorhome; usually travel at or below the speed limit, and he brakes lighter than when he drives his car. The vehicle is stored outside when they do not use it. And it has not been near the coast. The last time they drove it the brakes got hot again, the left front hub lost the oil, and the ABS light came on. The owner used to build and race cars, and he does the normal maintenance on the vehicle. He has not changed the brake fluid. When the brakes get hot, the braking power is diminished, the brake pedal gets harder, but the pedal has never gone to the floor.

**Inspection:** Prior to the arrival of the other participants, the technician repaired the leaking left front wheel bearing seal. The left hub cover, melted from the last thermal event, is displayed in Figure 5. He did not disturb the brake system. The vehicle was visually inspected by the group to check several obvious items and to insure it was safe to drive. The vehicle appeared to be in good condition. The brake-linkage bell crank was not equipped with a Zerk fitting but was found to operate normally. The brake fluid level and condition appeared to be normal, and the brake pedal was found to have normal travel. The data label from the ABS ECHU, which had some undercoating sprayed on it, is shown in Figure 6. There were multiple mud dauber wasp tubes on the frame rails, as shown in Figure 7, which could indicate the amount of use of the vehicle. The ABS sensors were examined and appeared to be in good condition. The accordion boots on the caliper slide pins appeared intact at all four wheel-ends. The rear-axle splash shields were removed for inspection of the brake rotors and for the installation of the infrared-temperature sensors. The caliper housings appeared to have been though different amounts of heating. The right front caliper had been replaced in early 2006 and had the factory paint intact, as shown in Figure 8. The brake rotor had been replaced and still appeared to be new, as shown in Figure 9. Since the replacement of this caliper and rotor two years ago, this brake appears to be working normally. The left front caliper was missing the paint on the middle "finger" of the caliper housing, as shown in Figure 10, which could indicate excess heat at that location. The left front brake rotor showed additional signs of overheating with lining transfer to the rotor and pitting, as shown in Figures 11 and 12. The rear brakes showed more evidence of overheating with the loss of paint on all three fingers of the calipers, brake lining transfer to the rotors and heavy pitting of the rotors, as shown in Figures 13 through 17. The Tech2 revealed the fault codes: 0031 "right rear wheel speed sensor circuit open or shorted", 0026 "left front wheel speed signal missing" and 0086 "ABS indicator lamp circuit shorted to battery". The fault codes were cleared. The initial residual-drag turning torques for each wheel was RF: 11 ft-lb, LF: 20 ft-lb, LR: 27 ft-lb, and RR: 24 ft-lb, measured using a VRTC-built lug nut crossbar[1] and a dial torque wrench with a maximum torque indicator. The leveling jacks were going to be used to lift the vehicle with two 2" x 12" x 12" boards under each jack, however, the on-board generator did not run and the "house", or non-engine, batteries were in poor condition.

**Results:** The vehicle was instrumented with four Sensotec pressure transducers (0 to 3,000 psi) and shown in Figure 18, four Omega infrared temperature sensors (0 to 1,000°F) and shown in Figure 19, a brake-pedal force transducer, and a GPS sensor connected to a Somat eDAQ data collection system, as shown in Figure 20. A Tech2 was also connected to the OBDII port and was used to monitor the vehicle-wheel speeds and error code status, but it was not connected to the Somat.

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1 As shown in Figures 4 to 6 in *"Trip Report to Jerry Greer RV Dealership"* 12/28/2007 available at http://nhthqnwws111.odi.nhtsa.dot.gov/acms/docservlet/Artemis/Public/Pursuits/2007/EA/INME-EA07016-27536.pdf

The vehicle was driven at 3:22 PM on 03/10/2008 for 44 miles. The ABS light was off, but a soft code was present for the left front ABS sensor (open). At the mid-point of the test, the RF brake rotor was measured with a Raytek MiniTemp MT Pyrometer. The inner swept area of the rotor measured 150°F and the outer 198°F, while the installed infrared temperature sensor recorded 179°F. The vehicle was driven back to the shop, the vehicle was raised, and the residual-drag torques were found to be RF: 12 ft-lb, LF: 20 ft-lb, LR: 88 ft-lb, and RR: 106 ft-lb. The residual-drag torques on the rear axle brake were much higher than expected and higher than what had been measured prior to testing or on a previous exemplar vehicle[2]. The temperatures during the drive were not extra ordinary, but there was an offset between the front and rear axles and the left and right sides of the rear axle. If the vehicle had been driven further, it is possible that the temperatures would have increased.

The next day the testing was delayed to repair the systems required to raise the vehicle so that the torque required to turn the wheels could be found any time abnormal temperatures were observed. The carburetor for the on-board generator, or auxiliary power unit, was replaced, the house batteries were replaced, the left front ABS sensor was replaced, and the ABS codes were cleared. The test drive started at 11:26 AM at 9,199 miles and intended to follow the route that the owners took to Kissimmee State Park. At 12:27 PM and 9,252 miles the vehicle pulled forcefully to the right during a braking event, however the brake temperatures appeared to be normal at RF: 219°F, LF: 220°F, LR: 339°F, and RR: 314°F. Then it was discovered that the route being taken was to the city of Kissimmee, not the state park. The driver detoured through Lake Wales to get to Kissimmee State Park. Along that route, a stop-and-go commercial strip area was encountered. This driving cycle was similar to the Hilton Test[3], and the rear brakes started heating up during a period without any pressure in the brake lines. The rear temperatures reached over 1,000°F, the drag on the engine was not noticeable to the driver, and the vehicle did not shudder or indicate a problem was occurring. Then suddenly the event was over and the rear temperatures declined. At 1:11 PM and 9,281 miles at the state park the temperatures had returned to normal. The vehicle was raised to measure the residual-drag torques and found the RF: 18 ft-lb, LF: 34 ft-lb, LR: 63 ft-lb, and RR: 16 ft-lb. However, the rear residual-drag torques were discounted. This model of motorhome would not allow the rear jacks to be extended while the parking brake was off and the transmission was in Neutral, as required to measure the residual-drag torque. The jacks would lower the vehicle to the ground when the transmission was shifted in to Neutral. The test was conducted after raising the rear axle as high as possible and measuring the residual-drag torque as the vehicle dropped. The rotation of the rear wheels did not feel normal. The motorhome was then driven to a lunch spot and parked for the preplanned two-hour cool down.

At 3:41 PM and 9,292 miles the drive back to the dealership was started along the path that the owners would have normally taken to the state park. The brake temperatures ran cooler, appeared normal, and more even on each axle than previous tests. The front axle temperatures were cooler than the rear axle temperatures, which could be

2 The residual-drag torque values found on an exemplar vehicle was 5 to 8 ft-lb on the front axle and 20 to 43 ft-lb on the rear axle, as shown in *"Trip Report to Jerry Greer RV Dealership"* 12/28/2007 available at http://nhthqnwws111.odi.nhtsa.dot.gov/acms/docservlet/Artemis/Public/Pursuits/2007/EA/INME-EA07016-27536.pdf

3 As described in *"Hammond, LA Workhorse-Bosch Trip Report"*, available http://www-odi.nhtsa.dot.gov/cars/problems/defect/defectsearch.cfm under EA07016.

attributed to more cooling air passing over the front brakes. At 4:45 PM and 9,339 miles the motorhome was back at the dealership. The vehicle was raised on the shop hoist and the residual-drag torques were RF: 14 ft-lb, LF: 26 ft-lb, LR: 55 ft-lb, and RR: 58 ft-lb. There was some drift in the zero pressure readings, so the brake bleeders were opened while the instrumentation pressure outputs were monitored. The brake line pressures read between 12 psi and -6 psi and did not change when the bleeders were opened. The rear leveling jack electrical diagram was inspected and found that raising the rear jacks, then removing the fuse would allow for field measurements of the residual-drag torque on the rear axle wheels. The data from the period when the rear brake temperature event occurred while driving through Lake Wales was studied and verified that no pressures were present during the 1,000+°F temperatures. This was deemed to meet the primary goal of this field inspection. Testing was planned for the following day to repeat the owner's course to Kissimmee State Park, delay two hours, then return via the Lake Wales course to gain another chance to measure the residual-drag torque during the high temperature event on the rear axle, if it occurred again. However, creating a thermal event was not desired since it might change the characteristics of the internal components of the calipers. The pending teardown of the calipers was deemed more important than conducting a Hilton Test and driving the calipers into overheating.

During the last day of testing, on 03/14/2008, the test drive started at 9:01 AM and 9,339 miles. After an eventless drive, the motorhome arrived at the state park at 10:24 AM and 9,397 miles. The vehicle was raised with two 2-inch thick boards under each leveling jack and the fuse pulled after the rear axle was in the air. The residual-drag torques were measured at RF: 24 ft-lb, LF: 33 ft-lb, LR: 64 ft-lb, and RR: 46 ft-lb. A short drive was made to the lunch spot, and the 2-hour cold soak was completed. At 1:04 PM and 9,404 miles the last leg of the test drive was started with the Lake Wales commercial strip section. At 1:28 PM and 9,420 miles some pulling of the vehicle to the right was noted, but the temperatures were normal and almost equally balanced left to right on each axle. The front-axle brake rotor was at 399 °F and the rear-axle brake rotor was at 499 °F. At 1:37 PM after two snubs, the front brakes were squealing and the steering wheel pulled to the right. At 2:25 PM at 9,471 miles the motorhome arrived back at the dealership and the residual-drag torques was measured at RF: 11 ft-lb, LF: 22 ft-lb, LR: 45 ft-lb, and RR: 40 ft-lb. The testing was completed, the vehicle was deinstrumented, and the group disbanded.

**Recommendations:** It is desirable to continue the participation in the joint Workhorse/Bosch meetings to assist in the determination of the root cause.

Daniel G. Pearse

Vehicle Safety Engineer
Defects Analysis Group
Vehicle Research and Test Center

# APPENDIX

**List of Acronyms**

| | |
|---|---|
| ABS | Antilock Brake System |
| EHCU | Electronic-Hydraulic Control Unit |
| DA | Defects Analysis Group |
| DC | District of Columbia |
| °F | Fahrenheit scale of temperature measurement |
| FL | Florida |
| ft-lb | foot-pound, a unit of torque |
| GPS | Global Positioning System |
| GVWR | Gross Vehicle Weight Rating |
| GVWRF | Gross Vehicle Weight Rating Front axle |
| GVWRR | Gross Vehicle Weight Rating Rear axle |
| IR | Infrared pyrometer |
| LA | Louisiana |
| LF | Left Front |
| LR | Left Rear |
| mi | mile |
| mm | millimeter |
| ODI | Office of Defects Investigations |
| RF | Right Front |
| RR | Right Rear |
| RV | Recreational Vehicle |
| Tech2 | GM Service Tool |
| TRW | manufacturer of auto/truck parts |
| VIN | Vehicle Identification Number |
| VRTC | Vehicle Research and Test Center |
| VRTC-DA | Vehicle Research and Test Center - Defects Analysis Group |

**List of Figures**

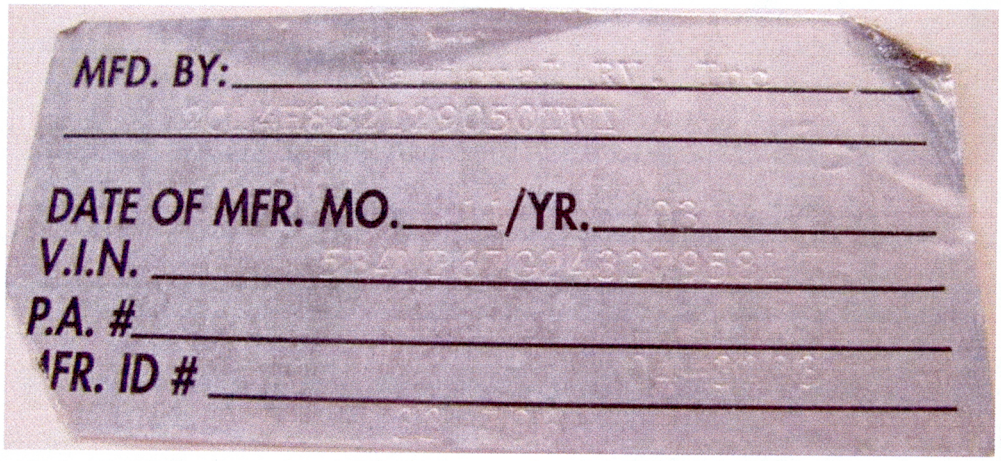


**Figure 1 – Data Plate of the National RV, Inc Sea Breeze LX Motorhome Inspected at Plant City, Florida**

MFD. BY: National RV, Inc, 2014H832129050TWX, DATE OF MFR. 11/03, V.I.N. 5B4MP67G243379581, P.A.# (blank), MFR.ID# 04-3203, 33-796


**Figure 2 - View of the Complaint Vehicle During the Initial Inspection**


**Figure 3 – The Sea Breeze LX Motorhome During the Installation of the Instrumentation**

**Figure 4 – Exemplar Photograph of the Sea Breeze LX Motorhome with One of the Slide-Outs Extended**

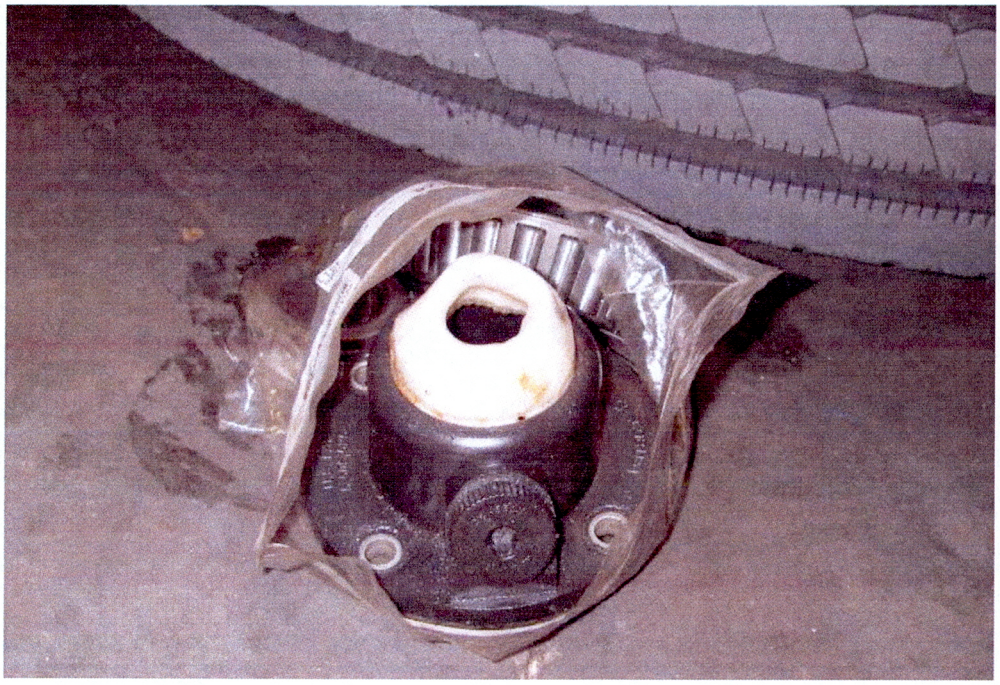

**Figure 5 – Left Hub Cover After the Owner Experienced a Hot Brake and Failed Inner Wheel Bearing Seal Just Prior to This Inspection and Testing**

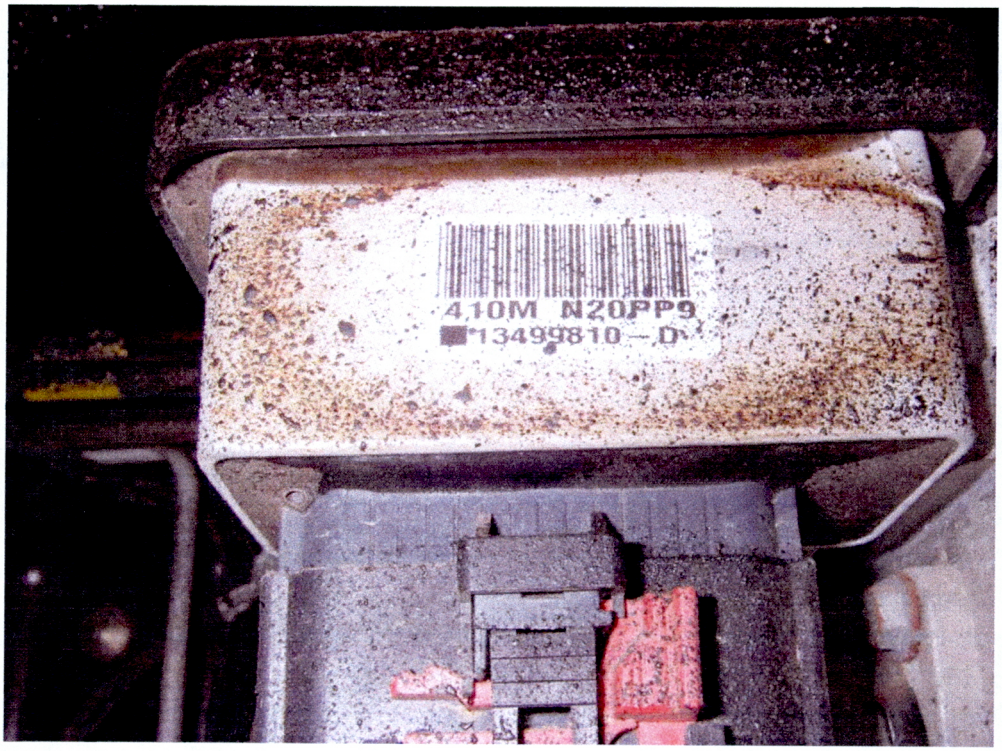


**Figure 6 – The TRW ABS EHCU Used by Workhorse is the Model 410M**

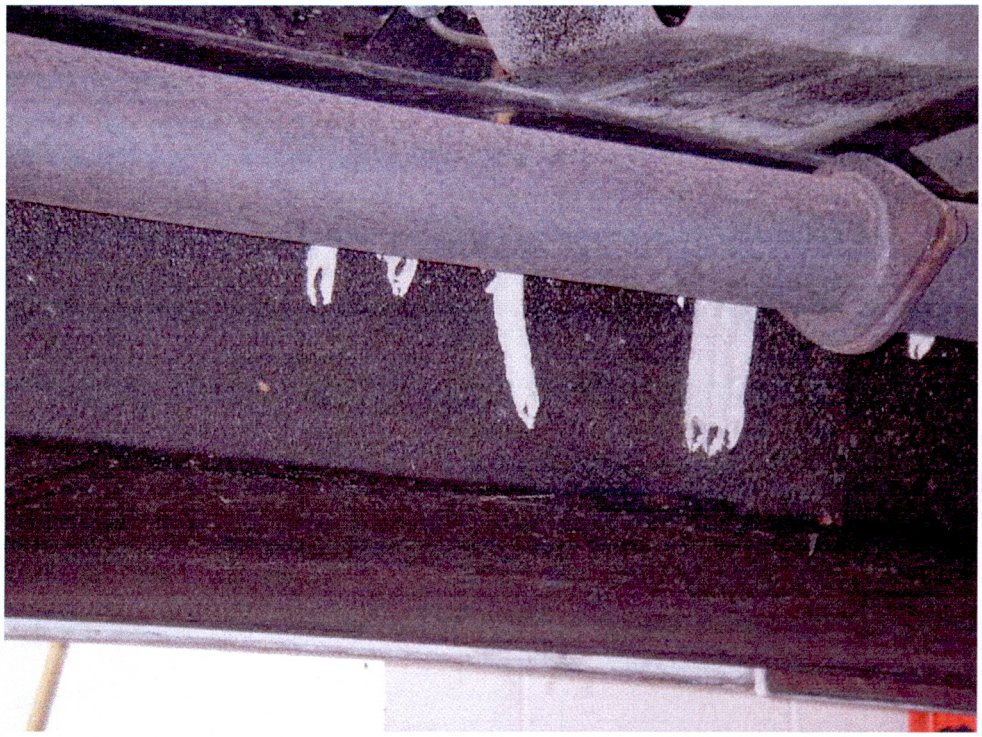

**Figure 7 – Mud Dauber Wasp Tubes were Found on the Frame Rails of the Motorhome That May Indicate the Level of Use of the Vehicle**

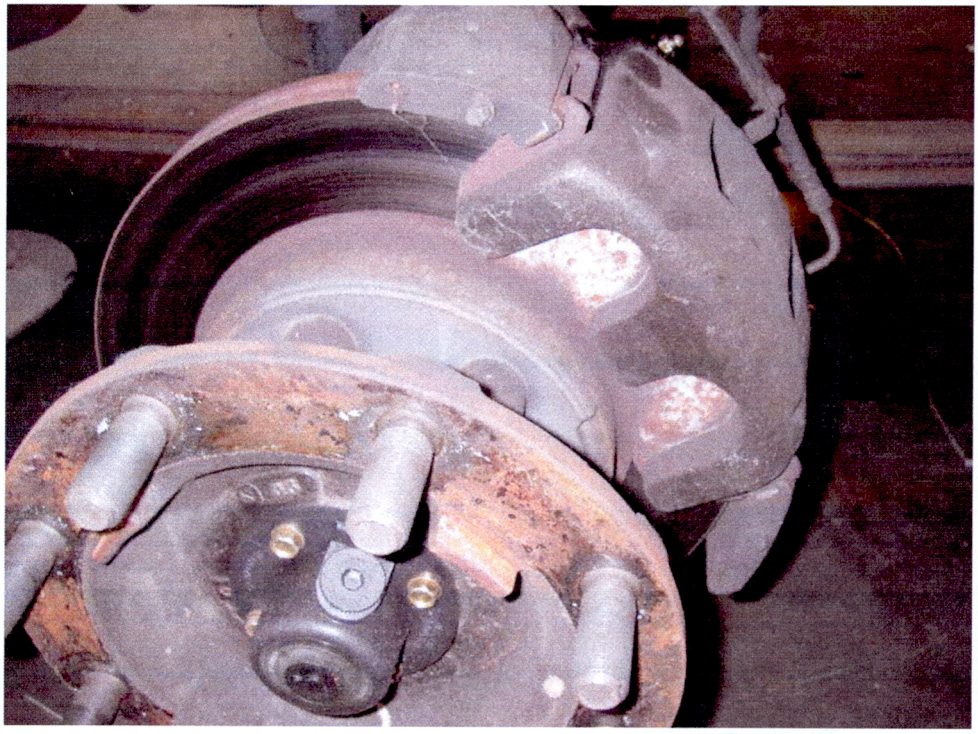

**Figure 8 – Overall View of the Right Front Brake Showing the Clean Rotor and the Paint on the Caliper Housing**

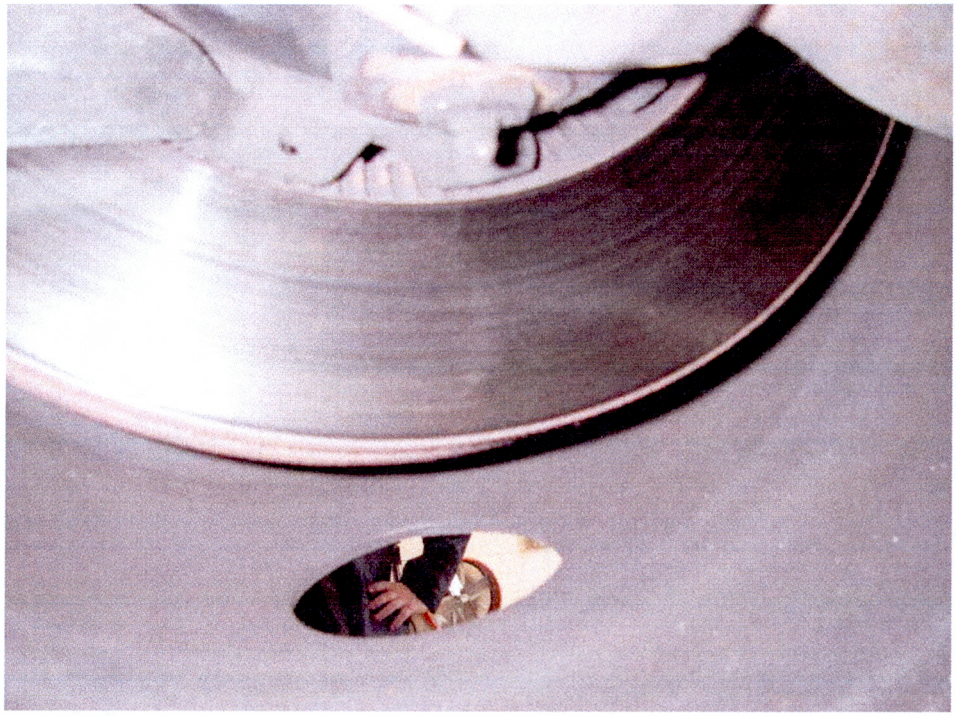

**Figure 9 – The Right Front Rotor had Been Previously Replaced and Still Looked New**

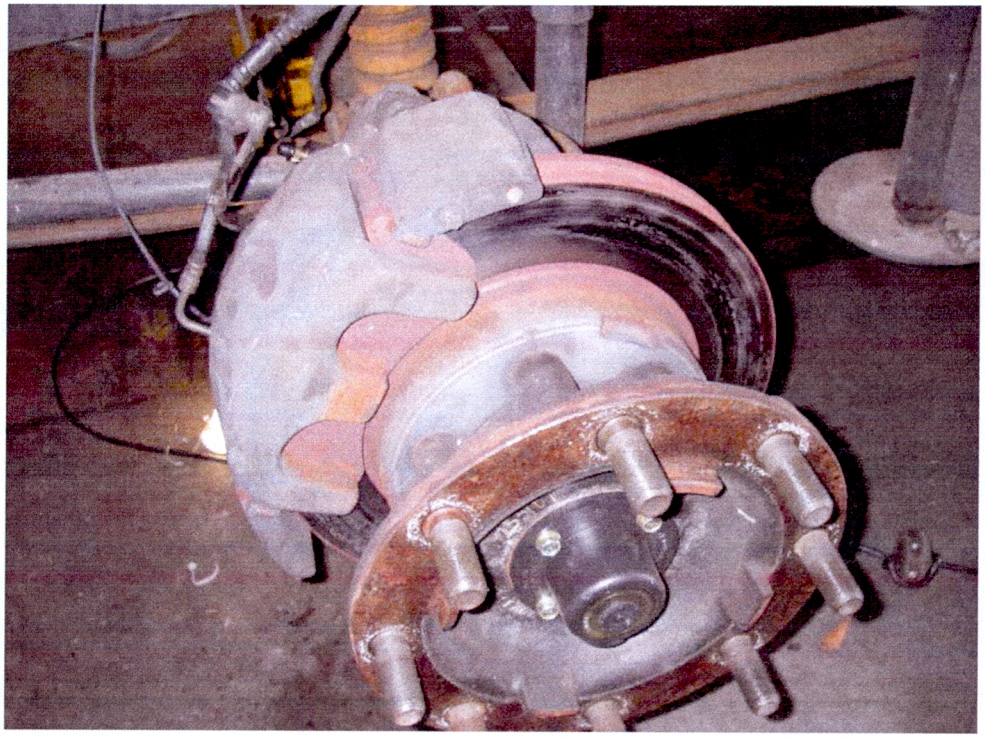

**Figure 10 – Overall View of the Left Front Brake Showing the Marks on the Rotor and the Paint Missing on the Center Finger of the Caliper Housing**

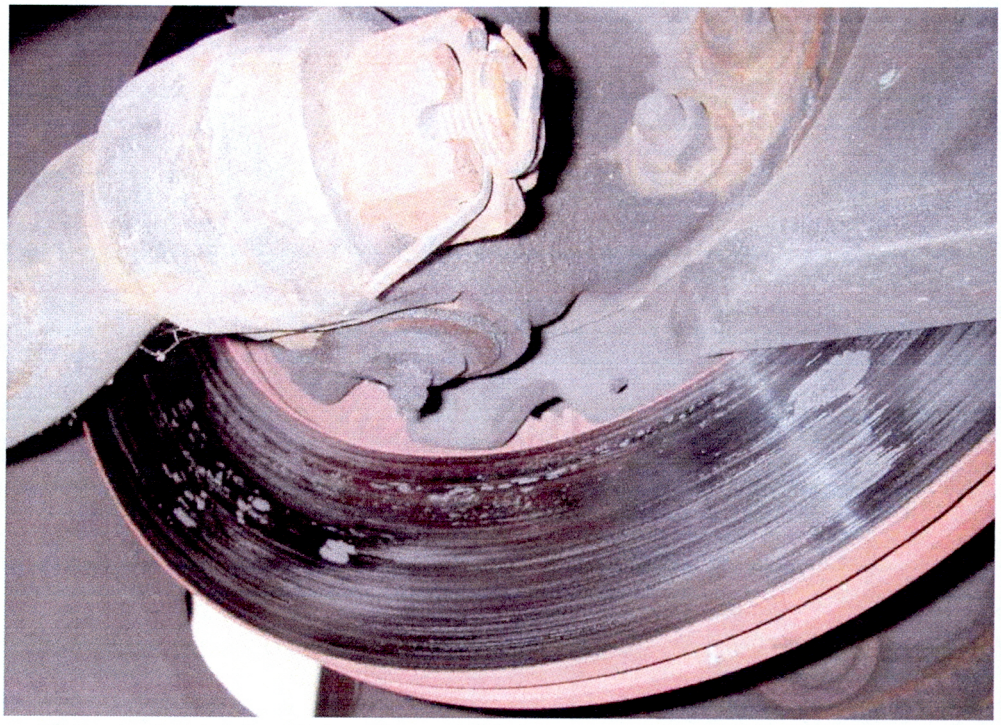

**Figure 11 – Lining Material Transfer and Pitting on the Left Front Brake Rotor, Indicating High Brake Temperatures**

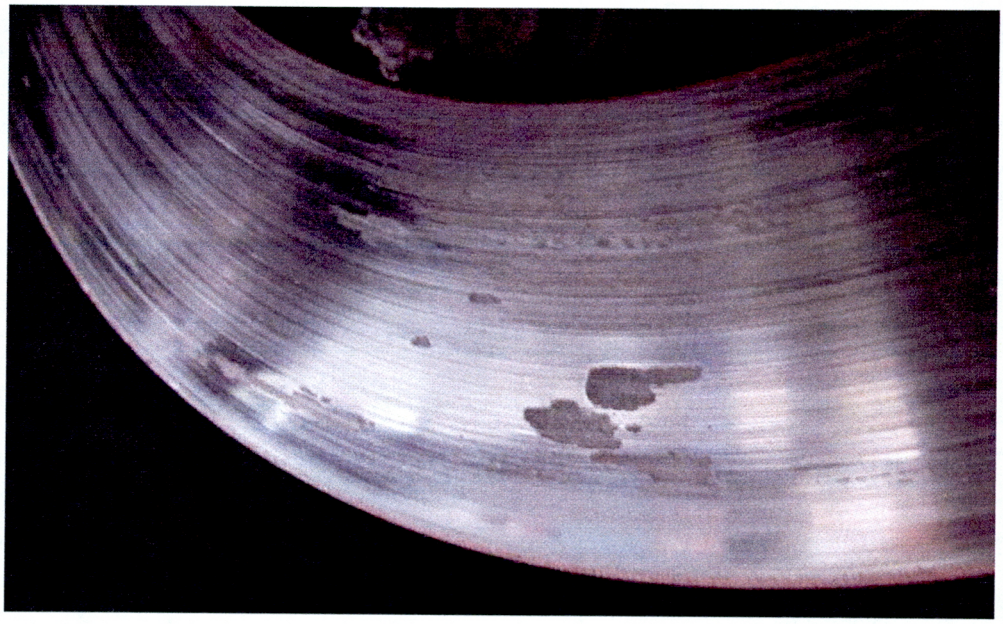

**Figure 12 – Another View of the Pitting on the Left Front Brake Rotor**

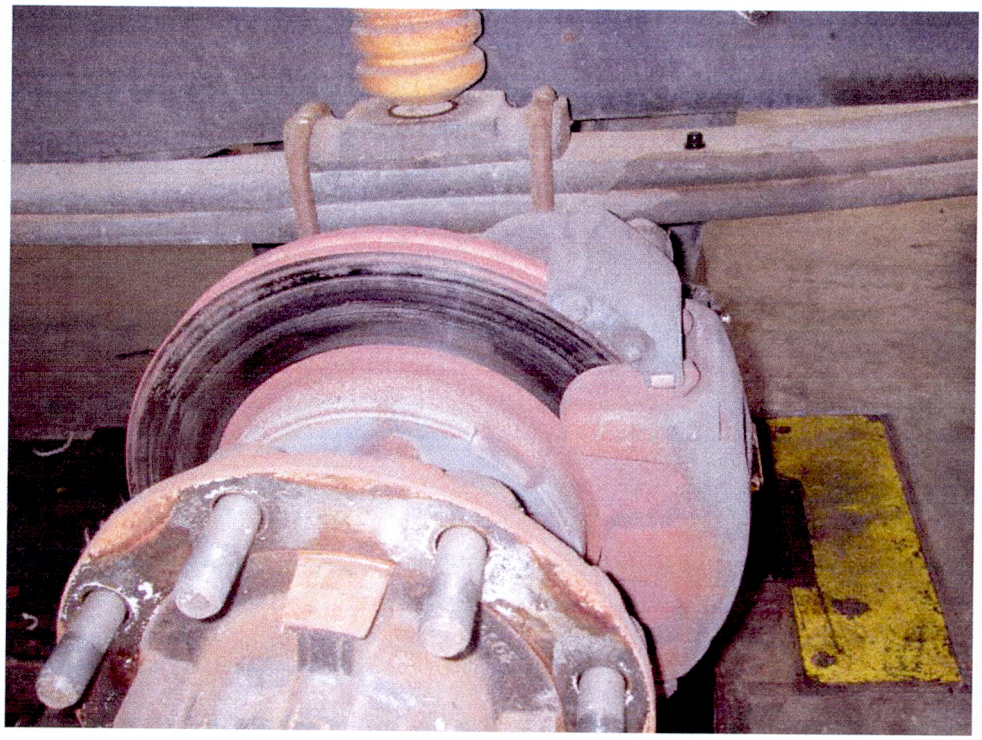

**Figure 13 – Overall View of the Left Rear Brake Showing the Marks on the Rotor and the Paint Missing From a Significant Portion of the Caliper**

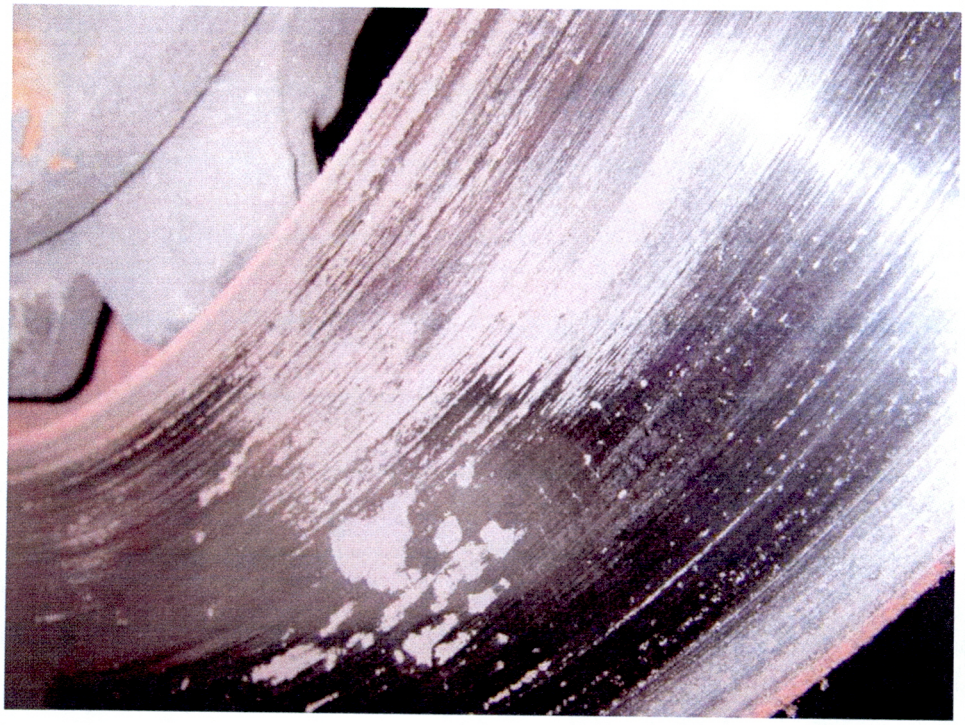

**Figure 14 – Left Rear Brake Rotor Showing the Material Transfer and Pitting of the Rotor Surface**

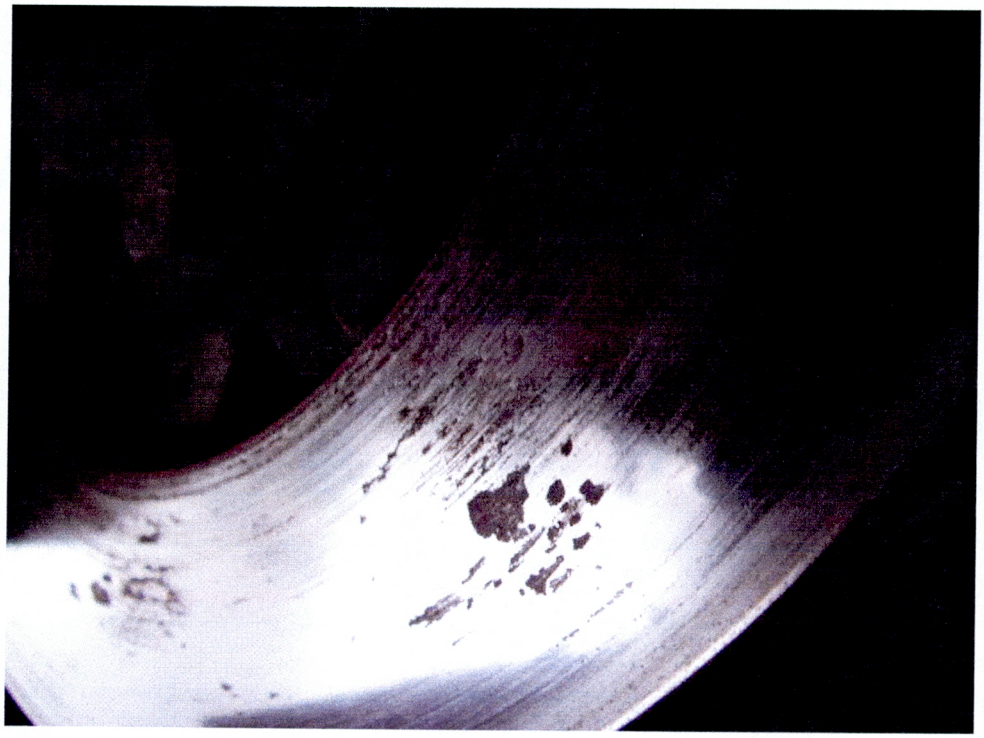

**Figure 15 – Another View of the Pitting on the Left Rear Rotor**

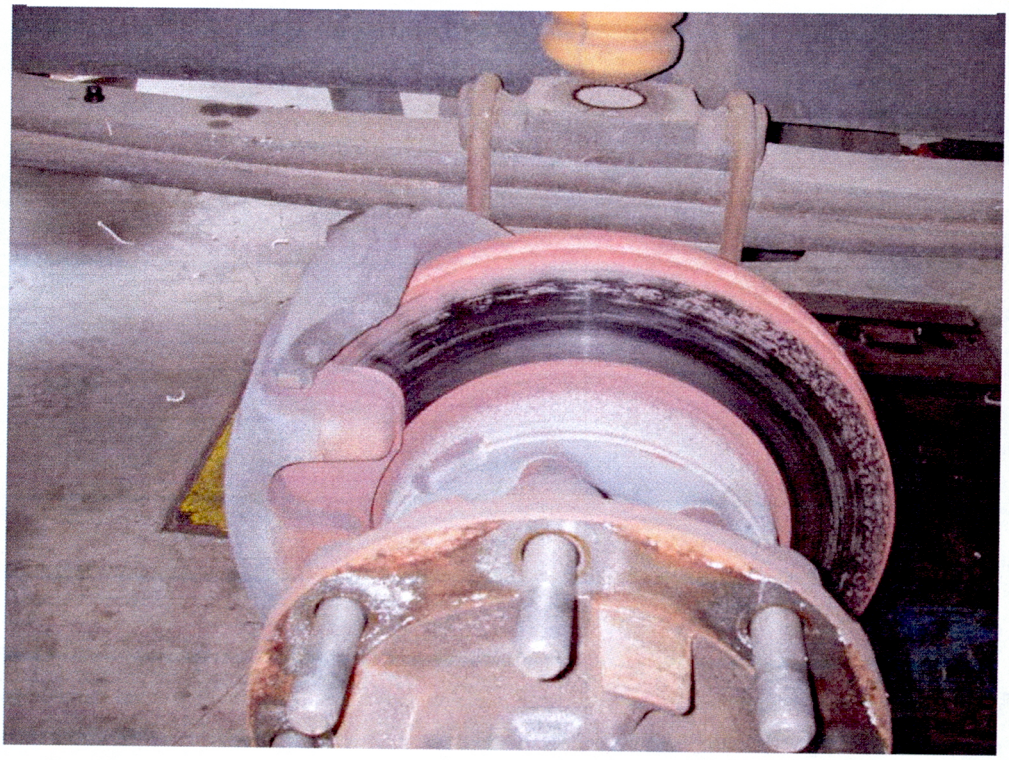

**Figure 16 – Overall View of the Right Rear Rotor Showing the Marks on the Rotor and the Paint Missing From a Significant Portion of the Caliper**

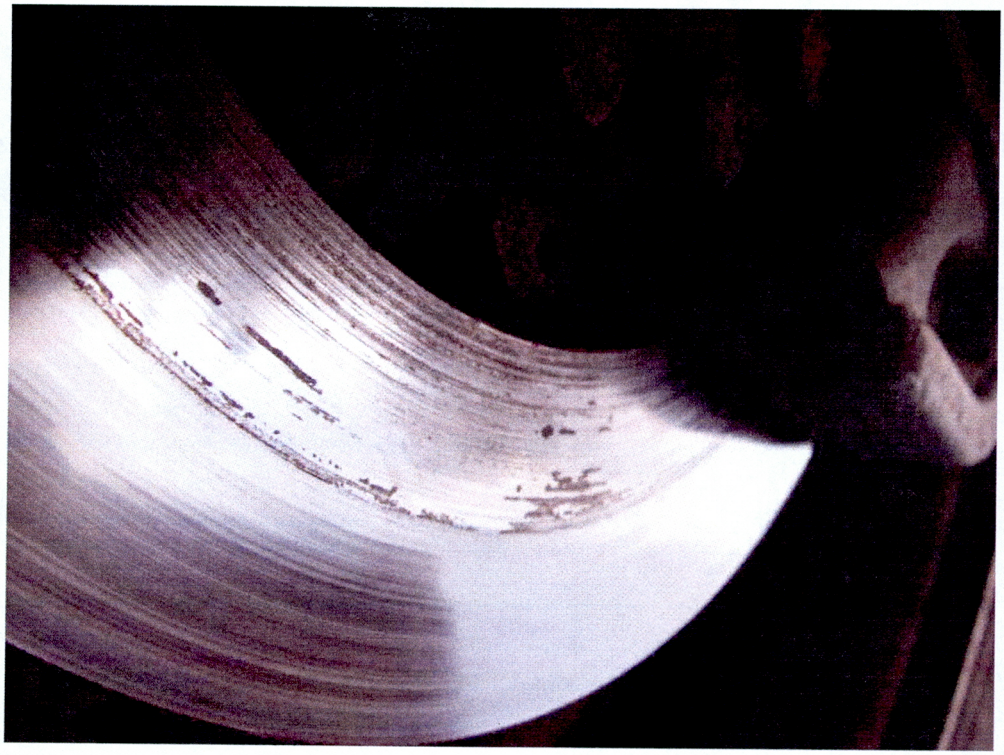

**Figure 17 – Pitting on the Right Rear Brake Rotor**

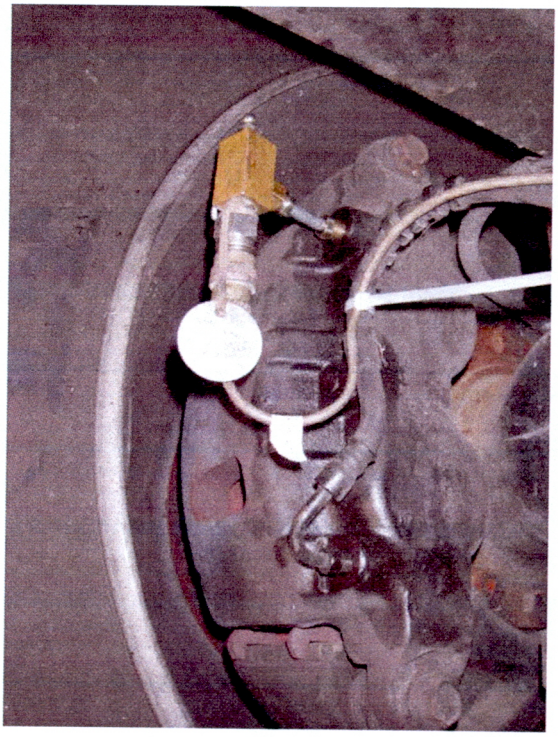

**Figure 18 – Bosch Provided the Pressure Transducers Installed in the Bleed Ports of the Calipers**

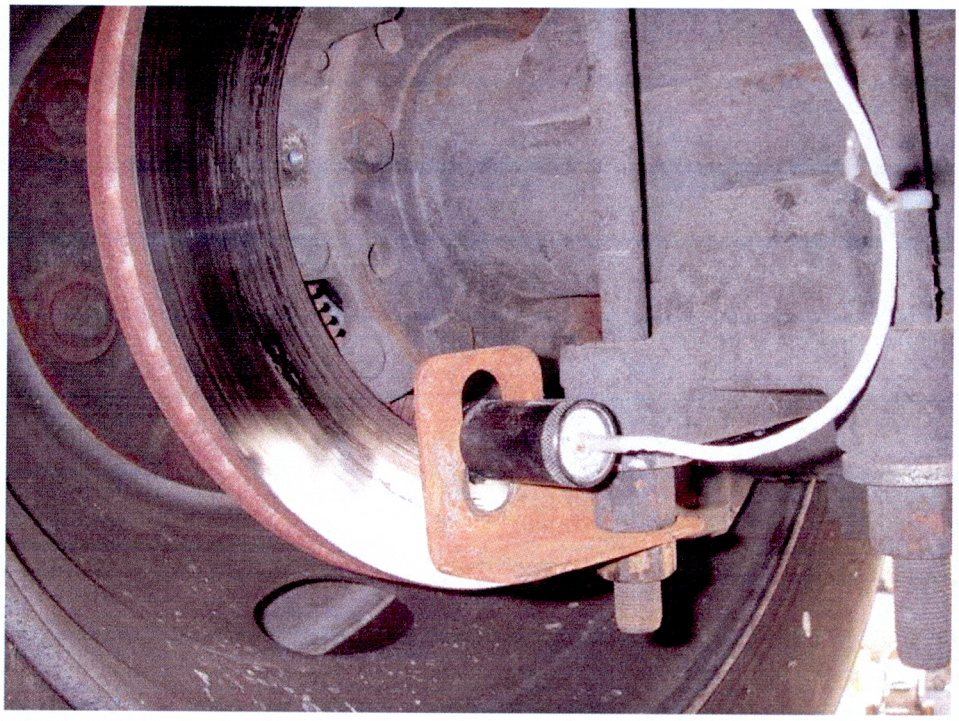

**Figure 19 – Workhorse Provided the Noncontact-Infrared-Rotor Temperature Sensors, Which were Aimed at the Middle of the Rotor**

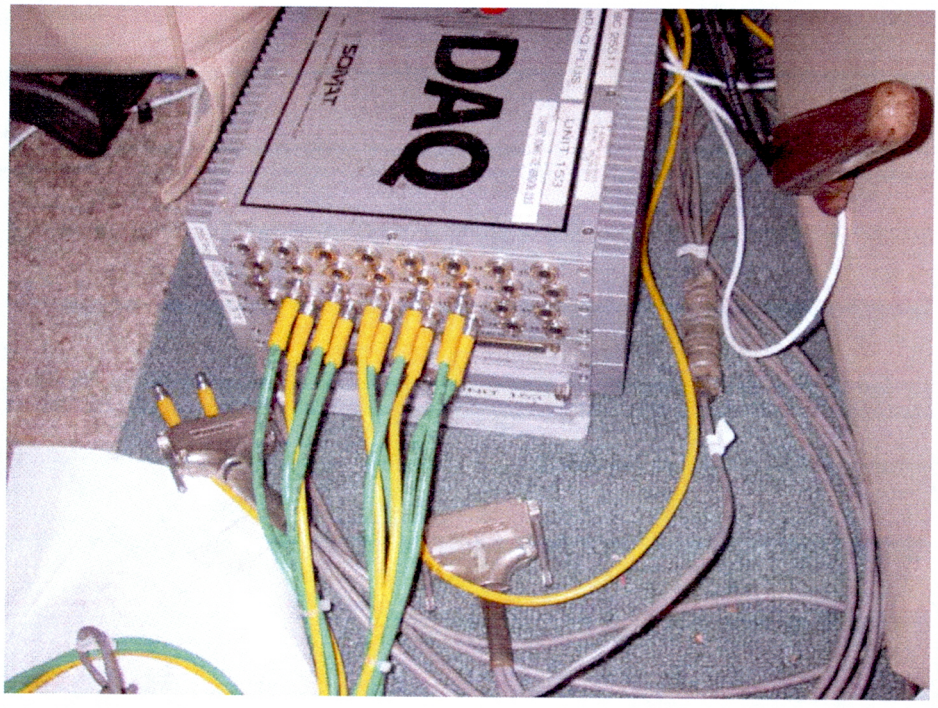


**Figure 20 – The Bosch Data Collection System Installed on the Motorhome was the Multilayered Somat eDAQ**