ODI RESUME

U.S. Department of Transportation
National Highway Traffic Safety Administration

OFFICE OF DEFECTS INVESTIGATION
NHTSA
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Investigation:	EA 09-010		
Prompted by:	RQ08-058		
Date Opened:	06/18/2009	**Date Closed:**	11/19/2010
Investigator:	Tom Bowman	**Reviewer:**	Bruce York-B
Approver:	Richard Boyd		
Subject:	Air Brake System		

MANUFACTURER & PRODUCT INFORMATION

Manufacturer:	NEW FLYER INDUSTRIES LTD
Products:	MY 2004 -2008 NEW FLYER TRANSIT VEHICLES
Population:	1,000
Problem Description:	DIMINISHED VEHICLE BRAKING / STOPPING PERFORMANCE

FAILURE REPORT SUMMARY

	ODI	Manufacturer	Total
Complaints:	0	0	0
Crashes/Fires:	0	0	0
Injury Incidents:	0	0	0
Fatality Incidents:	0	0	0

ACTION / SUMMARY INFORMATION

Action: Close this Engineering Analysis.

Summary:

INVESTIGATION HAS NOT IDENTIFIED A DEFECT. THERE HAVE BEEN NO REPORTED COMPLAINTS RELATING TO THIS ISSUE SINCE 2006. SEE CLOSING REPORT FOR FURTHER DETAILS.

MERITOR WABCO

Meritor WABCO Vehicle Control Systems
2135 West Maple Road
Troy, MI 48084-7121
Telephone 248.435.8001
Facsimile 248.435.8002
meritorwabco.com

ATTACHMENT A: Summary of Relay Valves Inspected Prior to Fleet Site Visit

Vehicle Information				Valve Sample Information			Leakage (No Del: 20 sccm Max, Del: 30 sccm Max)					Timing		Crack	Seal Damage (Y/N)	
Tracking #	Vehicle #	In-Service Date	Milage	Sample #	Make	Mfr Date	15 psi No Del	135 psi No Del	15 psi Del	60 psi Del	135 psi Del	Apply (0.125 sec Max)	Release (0,300 sec Max)	Pressure 4.6 +/- 1.5 psi	I/L Seal	Exh Seal
SR1043	511	5-Sep-05	148,295	NF-27	MW	1-Apr-05	> 5 LPM	100	50	550	40	0.122	0.219	4.2	Y	N
SR1043	512	6-Sep-05	152,339	NF-29	MW	15-Apr-05	> 5 LPM	> 5 LPM	40	3	140	0.128	0.228	4.7	Y	N
SR1185	712	19-Jul-07	75,690	NF-28	MW	9-May-07	5	110	60	50	50	0.123	0.216	4.7	Y	N
SR1185	711	17-Jul-07	75,429	NF-30	OEM	8-Aug-05	0	0	2	2	4	0.106	0.245	4.7	–	N

Parker
FluidConnectors

Parker Hannifin Corporation
Parflex Division
1300 North Freedom Street
Ravenna, OH 44266 USA
Phone (330) 296-2871
Fax (330) 296-8433

Subject: Stiffness and Percent Extractables Test Summary for Air Brake Tubing Field Samples (EA 09-010)

Date: June 8th, 2010

The following is a summary of the Percent Extractables and Stiffness testing performed on select [redacted] air brake tubing field samples supplied to Parker Parflex by Newflyer Industries for analysis. All of the tubing samples are ¾" OD Nylon 11 PFT air brake tubing manufactured by Parker Parflex. Small samples of the inner tube materials were submitted to Akron Rubber Development Laboratories in January of 2010 for Percent Extractables testing as well a control sample taken from a Nylon 11 tube from Parflex stock that had not seen any field use. The table below summarizes the ARDL test results from ARDL Test Report PN88727:

SAMPLE IDENTIFICATION			% EXTRACTABLES
SAMPLE #1 Nylon 11 Control			11.7
SAMPLE #2 Unit 512,	[redacted]	Inlet to dryer from separator	12.9
SAMPLE #3 Unit 512,	[redacted]	Copper to separator	6.3
SAMPLE #4 Unit 512,	[redacted]	SR 1043	6.5
SAMPLE #5 Unit 501,	[redacted]	Relay delivery to ABS modulator	11.0
SAMPLE #6 Unit 501,	[redacted]	Outlet to oil separator	6.0
SAMPLE #7 Unit 501,	[redacted]	Inlet to oil separator	6.1

SAE J844 stiffness testing was also performed on the above samples which were of sufficient length for the test apparatus (approximately 11" min). No ¾" OD Nylon 11 PFT air brake sample was available for use as a control since Nylon 11 PFT air brake tubing in that size is no longer manufactured by Parker Parflex. A ¾" OD Nylon 11 HTFL High Temperature Diesel Fuel Tube taken from new stock was sampled for testing. It should be noted, however, that the Nylon 11 resin used in HTFL contains approximately ½ the amount of plasticizer found in the Nylon 11 PFT air brake tubing resin. Note that samples were placed on a straightening rod and heated only long enough to remove sample curvature prior to testing. Heating was roughly 15 minutes at 230°F rather than the 24 hour soak at 230°F called out in the SAE J844 test in order to avoid driving off plasticizer from the tubing sample. While no test data for ¾" OD Nylon 11 PFT air brake tubing was found with only a 15 minute heat soak, it is estimated that the stiffness (force for flex around a 4.5" OD mandrel) would be approximately 50 lbs force. Current 1120 air brake tubing is manufactured from Nylon 12 with roughly the same amount of plasticizer as was found in Nylon 11 PFT air brake tubing. HTFL High Temperature Diesel Fuel Tubing is currently being switched to a Nylon 12 resin with roughly the same amount of plasticizer as was found in Nylon 11 HTFL. While Nylon 12 is typically stiffer than Nylon 11 with the same plasticizer level and should not be used for direct comparison, the ***difference*** in the stiffness between the Nylon 12 1120 air brake tubing and the Nylon 12 HTFL diesel fuel tubing would be comparable to the ***difference*** in the stiffness of Nylon 11 PFT air brake tubing and Nylon 11 HTFL diesel fuel tubing. For this reason, a ¾" OD Nylon 12 1120 air brake tube and a ¾" OD Nylon 12 HTFL diesel fuel

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Parker Hannifin Corporation
Parflex Division
1300 North Freedom Street
Ravenna, OH 44266 USA
Phone (330) 296-2871
Fax (330) 296-8433

tube were included in the stiffness testing. Test results are shown below:

SAMPLE IDENTIFICATION			STIFFNESS, LBSf
SAMPLE #2 Unit 512,	[redacted]	Inlet to dryer from separator	50.4
SAMPLE #4 Unit 512,	[redacted]	SR 1043	58.7
SAMPLE #6 Unit 501,	[redacted]	Outlet to oil separator	57.6
1120 Nylon 12 ¾"OD air brake tube			65.6
HTFL Nylon 12 ¾" OD diesel fuel tube			72.8
HTFL Nylon 11 ¾" OD diesel fuel tube			60.4

Nick Martino

Nick Martino

Sr. Project Engineer
Parker Hannifin Corp.
Parflex Division
1300 North Freedom St.
Ravenna, Ohio 44266
Telephone 330-298-4019
Fax 330-296-8433
e-mail: nmartino@parker.com

MERITOR WABCO

Process Development / Engineering Service Request

PDP NO:		Date Received	
		PDP Request #	

General Information

Originator:	Gerald G. Paoletti	**Origination Date:**	November 24, 2009
Project Title:	New Flyer/[redacted]Valve Evaluation		
cc	T. Soupal, P. Iyer, J. Fent		

Specific Project Objective - Abstract *(Continue on pg 2 if required or include an attachment)

Perform Input/Output, Timing and Leakage tests and a tear-down inspection on one relay valve and one E-8P foot valve per the test procedures described in the following specifications:

Relay Valve – 973 298 031 0_635A
Dual Brake Valve (E-8P) – 461 332 000 0_635

See the attached WT0028 Laboratory Service Request for Details.
This is a test PDP only. There is no effect on Hebron operations.

Subset of Another PDP?	☒ Yes ☐ No	**PDP #:**	09-102	**Customer Notification (PCN)?** (Req'd for changes to Cust. Level Docs)	☐ Yes (Submit WT0090) ☒ No
Supplier	Haldex	**Customers Affected**	New Flyer/[redacted]		
Anticipated Volume	N/A	**Requested By**	☐ Customer ☒ Internal ☐ Supplier		
Customer Specific PDP	☐ Yes ☒ No	**Dev. Request (DR) #**	N/A	**Business Unit**: C&B	**ITAR Activities Involved?** ☐ Yes ☒ No

Product Impact

Information Requested:			**PPAP**	**Material Status**
	☐ Release - (New Part / Print) ☐ Change - (Existing Part / Print) ☐ Obsolete ☐ Obsolete (w/ Replacement Release)	☐ Prototype Drawing Only / (Customer Proposal) ☐ Drawing Change Only ☒ Other (explain in abstract)	☒ No ☐ Internal ☐ Supplier PPAP ☐ Customer PPAP	☐ Make ☒ Buy ☐ Other (explain)

Replacement Part/Drawing Number	**CVA Pricing Required?**	**Shelf Life Requirement?**	**Cost Request Required?** (Required for New Release)
	☐ Yes ☒ No	☐ Yes (Attach Requirements) ☒ No	☐ Yes (WT0080/WT0095) ☒ No

Inventory Impact

Parts Disposition: (If 'other', briefly describe)		**Prototype Build Date**	**Materials Implement Date**
☐ Running Change ☐ Rework Inventory ☐ Scrap	☐ New Part ☒ Other_____NONE_____		
		Production Parts Delivery Date	**Estimated Project Completion Date**
			1/11/2010

Authorization

	DEVELOPMENT TYPE
☐ **ACCEPT** ☐ **REJECT**	☐ Type A ☐ Type B ☐ Type C ☐ Type D ☐ Type E ☐ Type F ☐ Type G ☐ Type H ☐ Type I ☐ Type O ☒ Testing

ASSIGNED TO: (Project Leader)	Mark Roe	Individual / Team Leader	Team Selected :		
APPROVAL :			(Where applicable (i.e. Type F Projects)		

MERITOR WABCO

Laboratory Service Request

☒ Lab ☐ Track ☐ Field

To: Meritor [redacted] Engineering Test Group Mgr or Laboratory Supervisor		Date 11/24/2009
PDP Number (if applicable) 09-102-1	Test Number (assigned by Test Group Mgr or Lab Supervisor) LSR 354 30NOV09	Reference Number (assigned by Test Group Mgr or Lab Supervisor)
Requested By G. Paoletti	Requested Completion Date 1/11/2010	Requested Documentation Full Report
Date Parts Available 11/24/2009	Parts Disposition Return to Requester	Approved By

Project Title
New Flyer [redacted] Valve Evaluation

Objectives
Determine the operational effectiveness of the valves on the bench and provide inspection results on the seal condition as well as the contamination present in the valves.

Work Requested

1. Perform the following bench tests using the procedures outlined in product specification 973 298 031 0_635A for the relay valve and 461 332 000 0_635 for the foot valve:
   a. Leakage
      i. Relay Valve per section 2.2.A. through 2.2.D.
      ii. Foot Valve per section 2.2.A. and 2.2.B.
   b. Input/Output
      i. Relay Valve per section 2.1.A. on Primary Control Port Only and document the crack pressure at 2psi of delivery pressure ($P_{delivery} – P_{control}$)
      ii. Foot Valve per section 2.1.A.
   c. Apply/Release Time
      i. Relay Valve per section 2.1.B. with pressure applied to Both Control Ports Only
      ii. Foot Valve per section 2.1.C. Healthy Condition Only
2. Upon completion of the bench tests, perform a tear-down inspection of the valves. Take pictures showing the various internal cavities, underside of the pistons and condition of the inlet and exhaust seals. Remove the seals, if necessary to show any damage. Rate the type and amount of contamination per the scale provided in PDPs 09-102. Also rate the extent of damage to the inlet/exhaust seals.
3. Provide summary tables indicating:
   a. Relay Valve leakage, apply/release time (3-run avg) and crack pressure and a sample plot of the apply time, release time and input/output cure, as well as a plot of control and Delivery vs. time on the ramp-up
   b. Foot valve leakage, apply and release time and summary of important parameters, sample plots of apply/release and travel vs. delivery on apply and release for primary and secondary circuits
4. Bag the inlet seals, exhaust seals, inlet/exhaust tubes and valve bodies in separate individual baggies for delivery to the materials engineering for chemical evaluation.

Work assigned to Robert Wells	Documentation assigned to Robert Wells	Originator Completion Concurrence
Work completed (Initial/Date) Robert Wells 12/18/2009	Documentation completed (Initial/Date) Robert Wells 01/ 13 / 2010	Documentation Name and Location 09-102-1, [redacted] Valve Evaluation, 11-24-2009.docx N-Drive. SUP Folder

Results / Remarks

Engineering Summary

A visit was made to [redacted] to perform vehicle timing tests, stopping distance measurements and remove valve, air dryer and condenser samples from two New Flyer buses in the fleet. The relay valve from bus 501 and the foot valve from bus 512 were removed for bench testing, teardown, seal hardness measurements and chemical testing. The relay valve from bus 512 was previously removed and tested under the New Flyer field sampling activity. Reference PDP 09-102/LSR-300 for bus 512 relay valve results.

Bus 501 Relay Valve:
The relay valve showed excessive leakage at lower supply pressures, but tended toward sealing at full system supply pressure (135psig). The apply time was slower than expected and more than twice the limit of a virgin unused relay valve. The crack pressure and the input/output characteristics were within the expected performance of a virgin valve. Teardown inspection showed some evidence of sticky and oily contamination in the valve. Both the inlet and exhaust seals were shown to have damage. Materials analysis showed excessive softening in both the inlet and exhaust seals, with the inlet seal more significantly affected. A chemical contaminant was found, similar to that in some of the previous New Flyer relay valve field samples.

Bus 512 E-10P Foot Valve:
The foot valve timing and input/output performance was compared to benchmark averages from six virgin valves. The valve leaked excessively in both applied and non-applied conditions. This audible leak was found to be caused by a cut o-ring between the primary body and the steel spring adapter body. The valve primary and secondary apply times were faster than the benchmark average, but the release times were slower than the benchmark average. The valve required more travel and higher force to open the primary delivery than the benchmark average. It also had less available force (0.7lb) and travel (0.009”) at full release (Secondary Delivery = 0psig). Teardown inspection revealed oily contamination in both the primary and secondary cavities and on both pistons. Both inlet/exhaust seals showed some wear at the seat contact points. Materials analysis showed slight changes in hardness of the inlet/exhaust seals, slightly softer for the primary and slightly harder for the secondary. A chemical contaminant was found, similar to that in some of the previous New Flyer relay valve field samples.

Reference ArvinMeritor Laboratory Service Request 31293-6 for seal hardness and chemical analysis details.

The relay valve removed from [redacted] bus no. 501 and the foot valve removed from [redacted] bus no.512 during the October 2009 site visit were tested for leakage, input/output performance and apply & release timing to determine the general performance. Afterwards, a teardown inspection was performed and the parts were delivered to the Materials Engineering group for chemical analysis.

Bus 501 Relay Valve

Leakage:

Bus 501 Relay Valve Leakage (sccm)				
Non Applied (Sup Only)		Applied		
15psi	135psi	15psi	60psi	135psi
3500	7	340	>5000	180

The valve showed excessive leakage in the applied condition, but was much less at full system pressure (135psig). In the no-delivery condition (valve off), the valve leaked excessively at low pressure. When supply pressure was increased to 135psig, the valve leaked in excess of 200sccm, then slowly began to seal itself until stabilizing at 7sccm.

Crack Pressure & Timing

Bus 501 Relay Valve					
Crack Pressure (psig)	Time (sec)				
		Apply, 0-60psi		Release, 95-5psi	
	3-Run Avg	Del 1	Del 2	Del 1	Del 2
4.5	Run 1	0.234	0.244	0.237	0.235
	Run 2	0.243	0.243	0.238	0.236
	Run 3	0.244	0.244	0.237	0.236
	Average	0.240	0.244	0.237	0.236

Crack Pressure and release time was within the expected range of a virgin unused valve. The apply time was reduced from the expected range of a virgin relay valve. Figure 1 and 2 show one run each of the Apply time and Release time measurement:

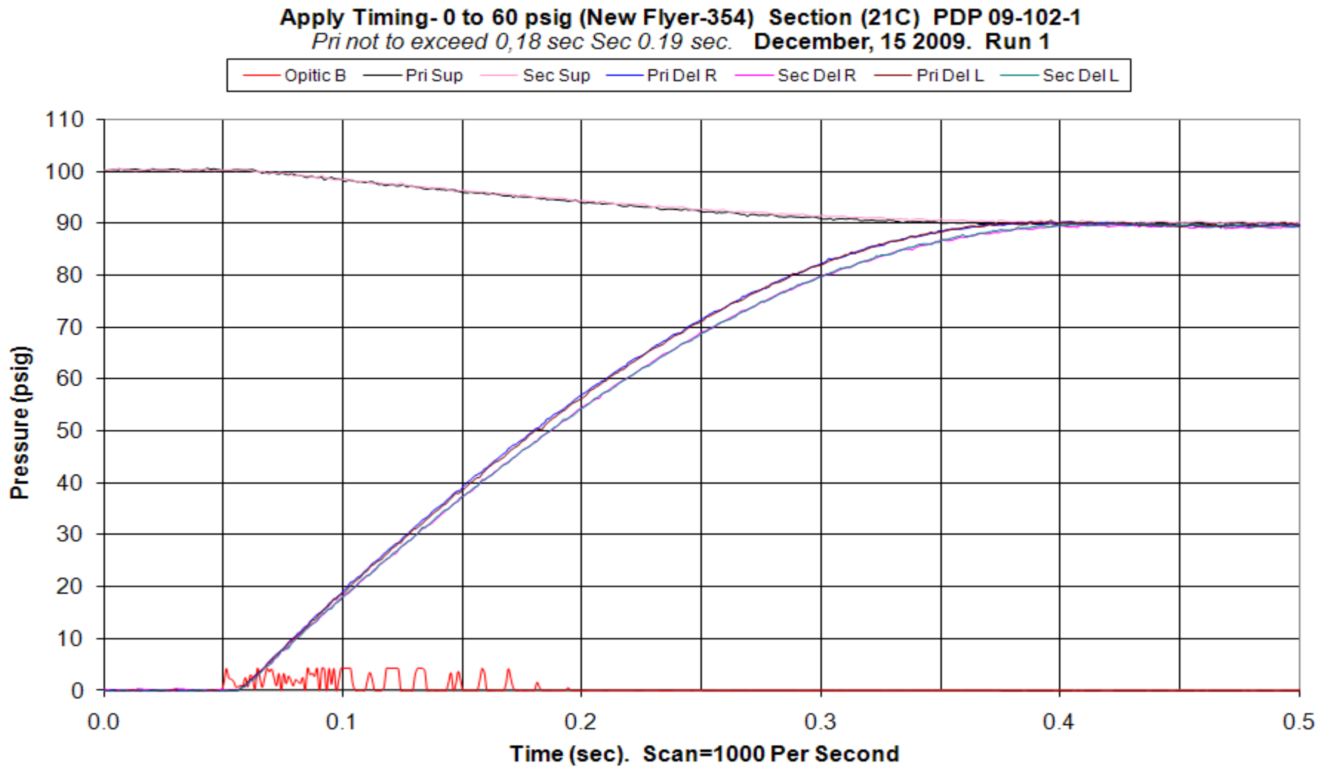


Figure 1: Apply Time

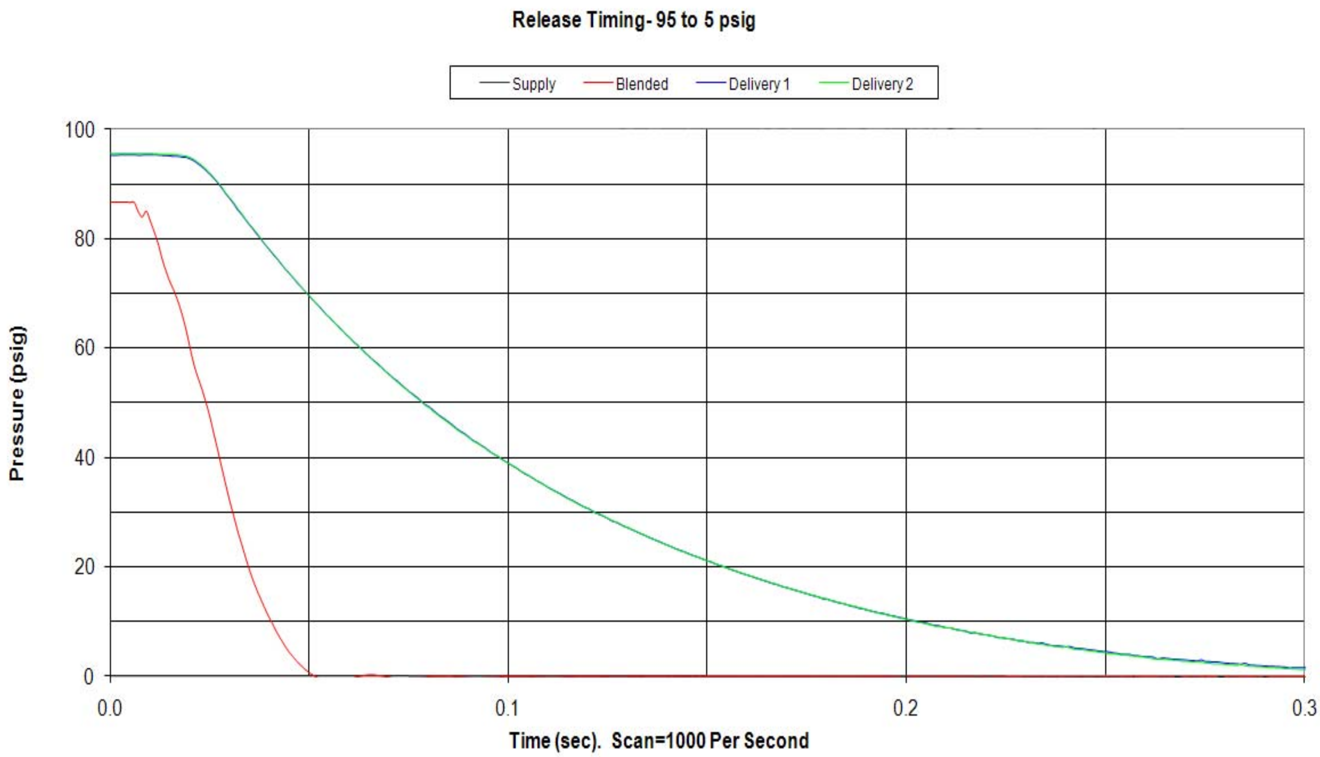


Figure 2: Release Time

Input/Output

The Input/Output performance of the valve operated as expected for a new virgin relay valve. Figures 3 and 4 below show the delivery pressure vs. control pressure on apply and release. Figure 5 shows the Control and Delivery pressure as a function of time.

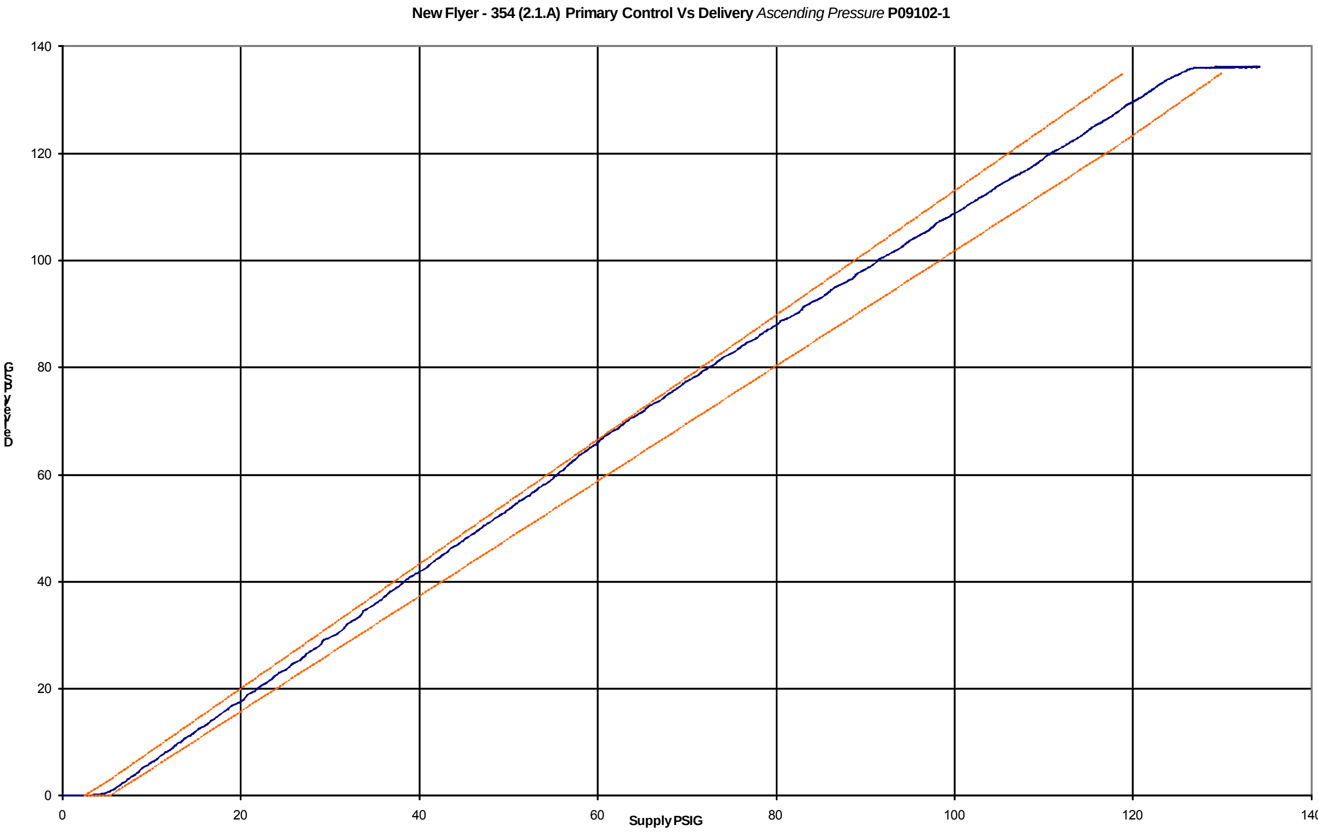


Figure 3: Delivery vs. Control – Apply

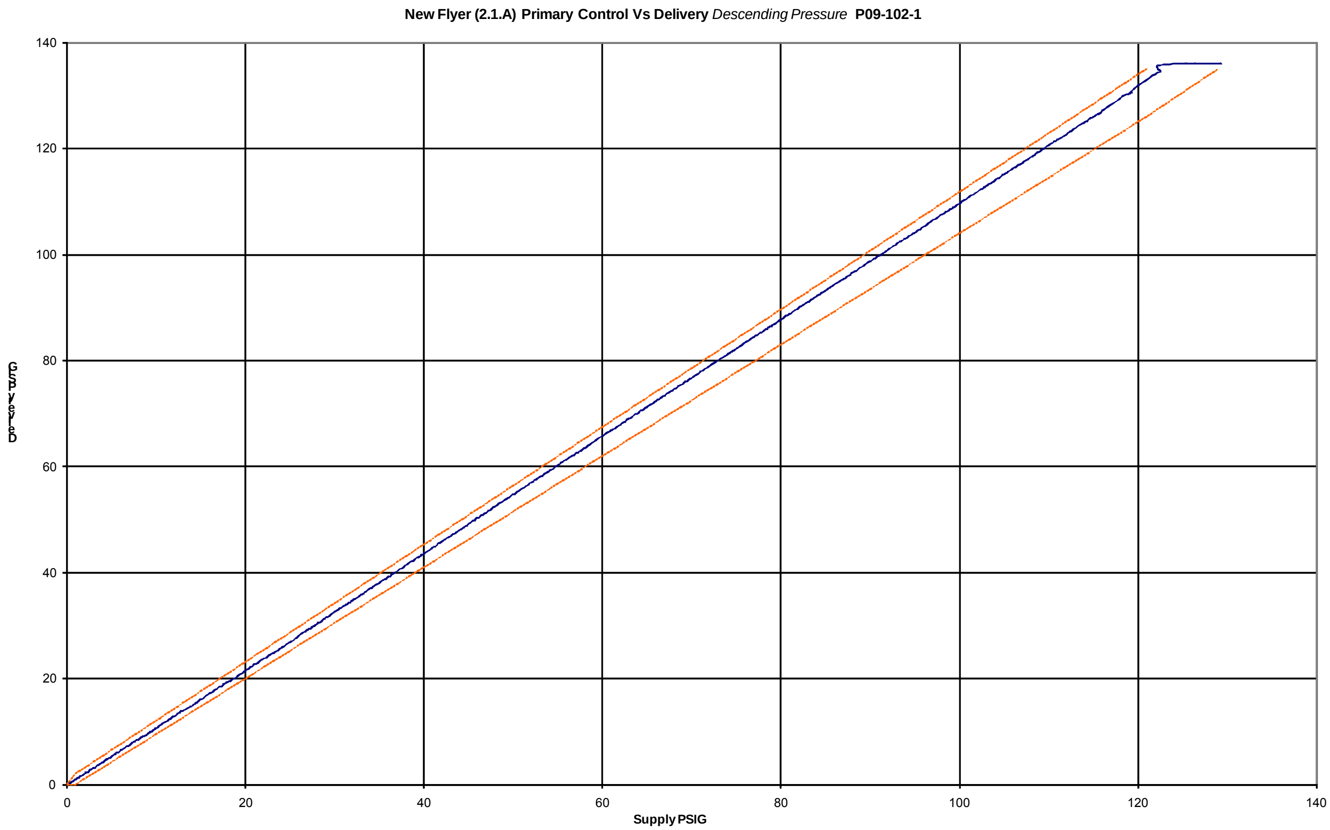


Figure 4: Delivery vs. Control – Release

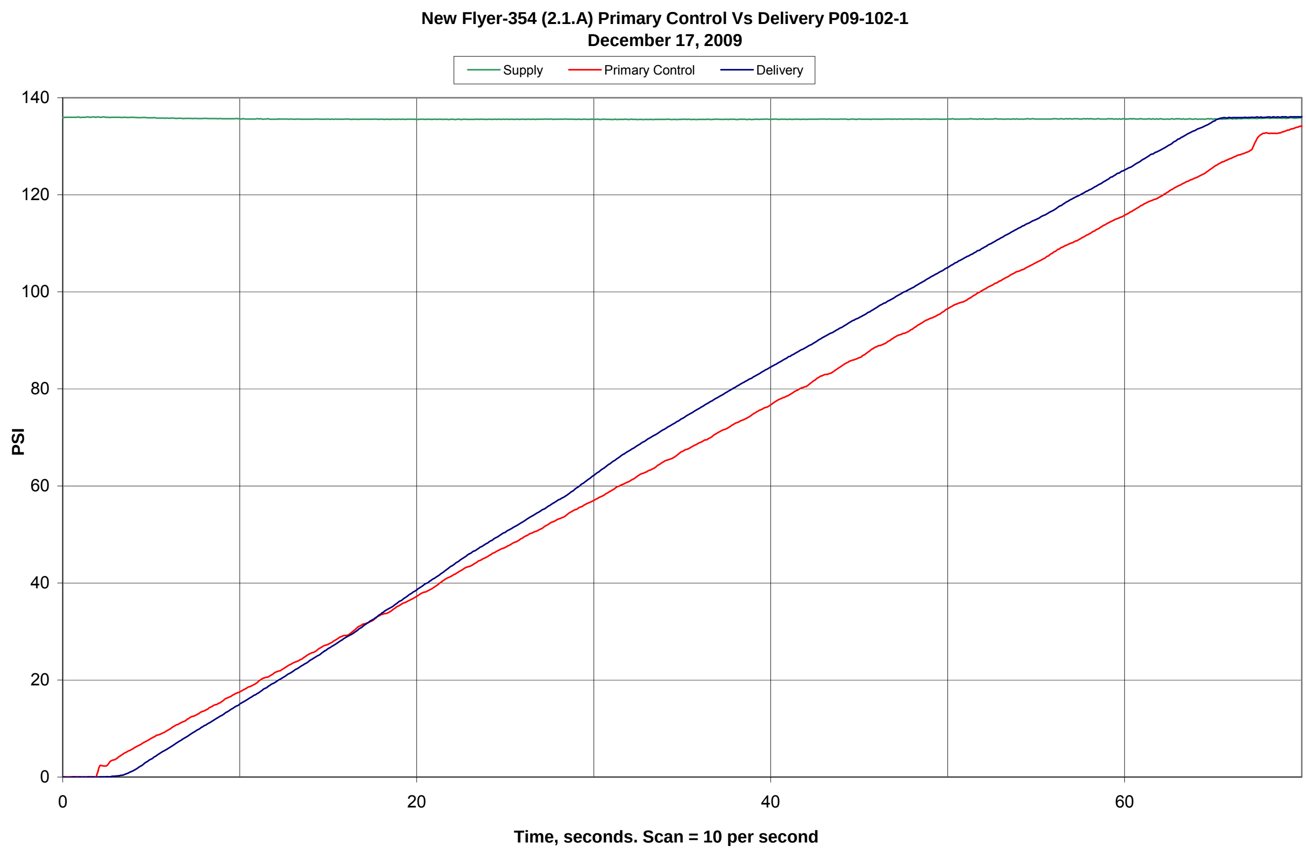
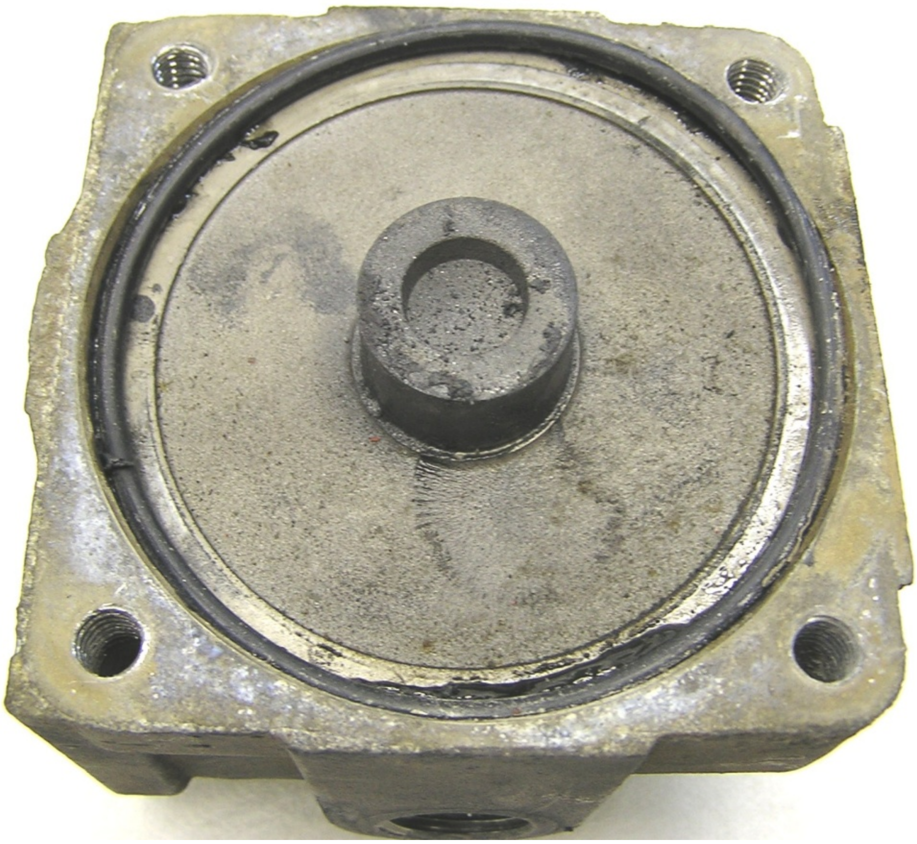


Figure 5: Control & Delivery vs. Time – Apply

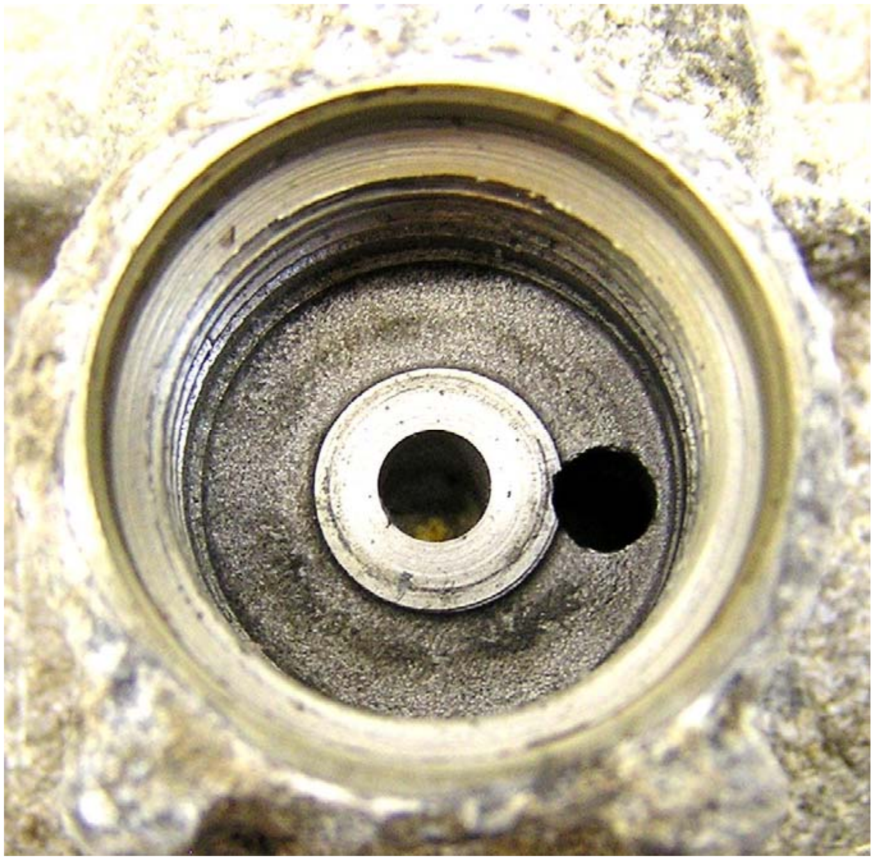
Teardown Inspection

The valve was then disassembled to check for any liquid or particulate contamination and determine if any seal degradation has occurred. The valve had a moderate amount of greasy, oily deposits in the internal delivery cavity, as well as the underside of the piston.

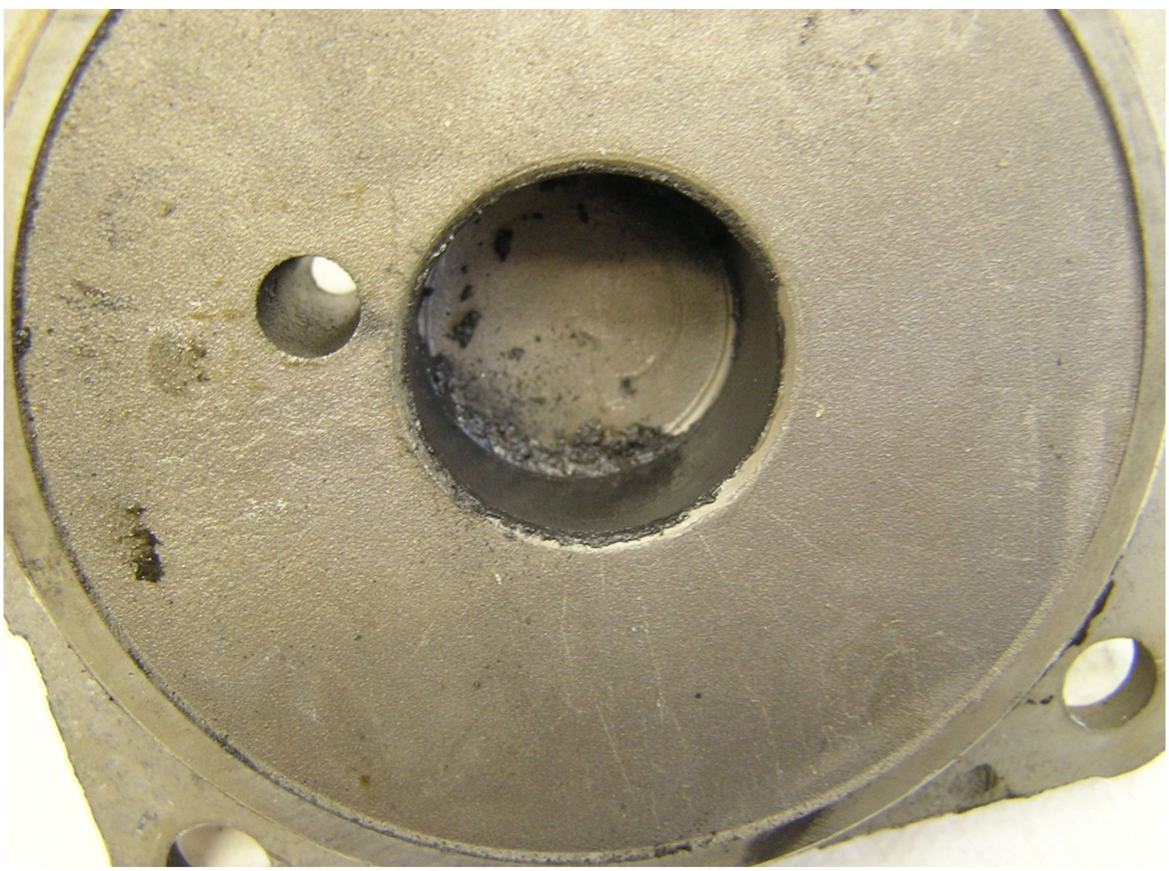
The Inlet seal was swollen and pitted around the seat landing area had a significant amount of set. The exhaust seal had a deep cut where the seat lands on the seal. The following pictures show the internal valve cavities and the inlet and exhaust seals:



Top of Piston with Cover O-Ring



Check Valve Cavity

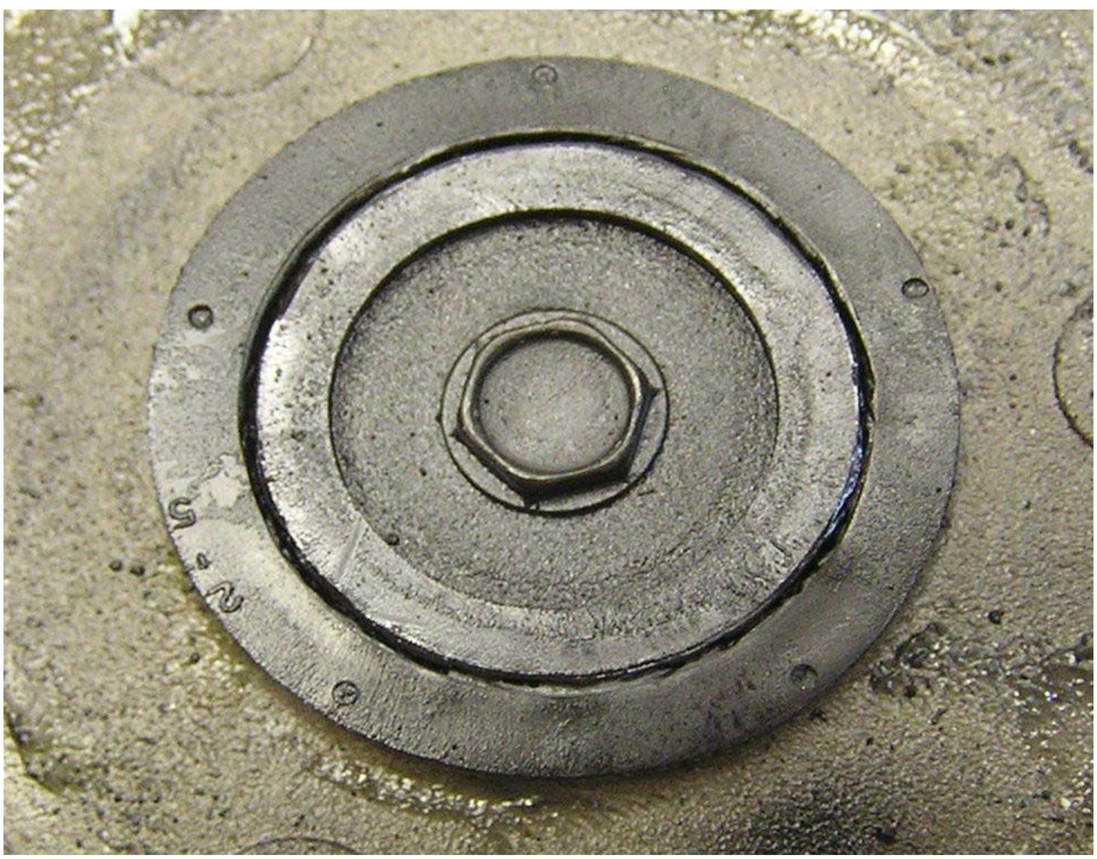


Top Cover (Piston Guide)

Top of Piston with Sticky Deposits

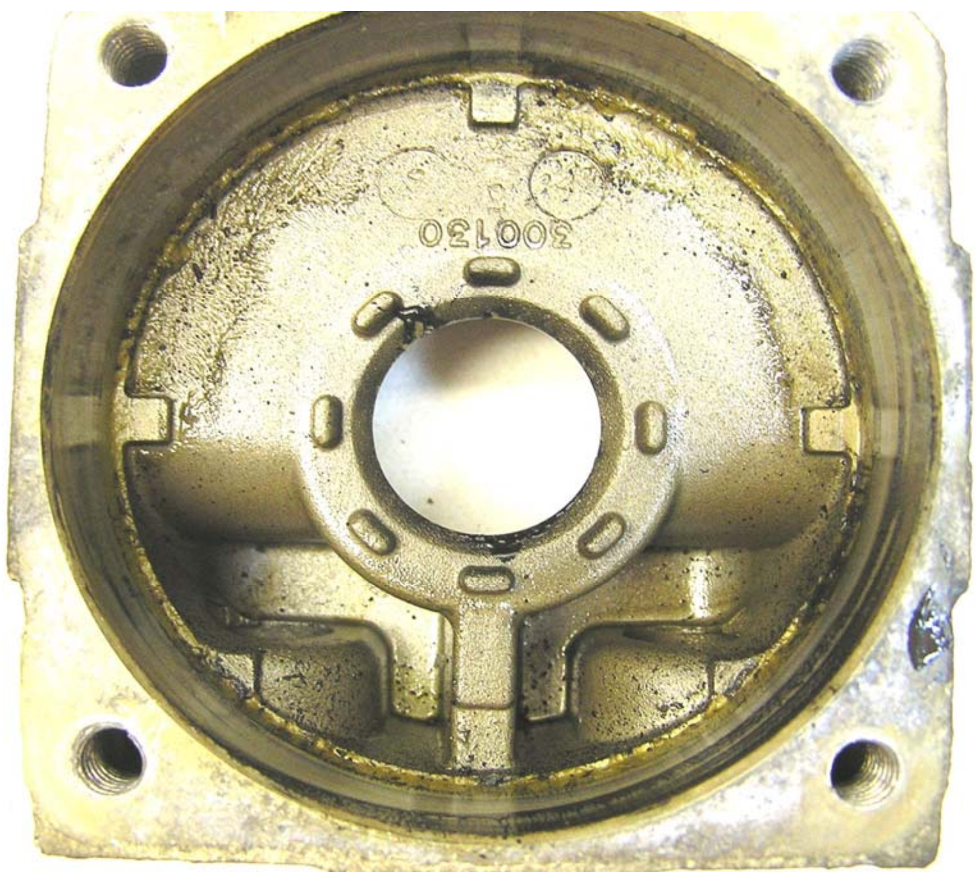
Top of Piston with Sticky Deposits

Piston O-Ring



Exhaust Seal & Piston Underside

Modulation Tube with Inlet Seal and Exhaust Seat



Delivery Cavity

Supply Cavity and Supply Seat

The valve was then forwarded to the Materials Engineering laboratory to check for changes in seal hardness and the presence of chemical contamination in the internal valve cavities. Seal hardness was tested using a Wallace microhardness tester. The results were reported in degrees IRHD.

Bus 501 Relay Valve		
Seal	Seal Δdu	Contamination Present (Y/N)
Inlet	-32	Y
Exhaust	-6	

The above table shows the results of the chemical and rubber evaluation. The seal hardness testing revealed some softening in the exhaust seal with a difference of 6° IRHD compared to a like seal from a virgin valve. The inlet seal had a difference of 32° IRHD compared to a like seal from a virgin valve. The chemical wash of the internal valve cavities showed a contaminant present which is similar to that found in several of the previous New Flyer field samples. Refer to ArvinMeritor Laboratory Request 31293-6 for details.

Bus 512 Foot Valve

Leakage

The valve showed a significant leak upon application of the foot valve. No leakage in the "Primary Failed Condition" (no primary supply pressure and supply ports open to atmosphere) indicate the leakage to be in the primary circuit. A cut o-ring was later discovered between the primary body and the plunger spring body, causing a direct leak path from the primary delivery cavity to atmosphere.

Bus 512 Foot Valve Leakage (sccm)							
Non Applied (Sup Only)		Applied			Failed Primary Applied		
15psi	135psi	15psi	60psi	135psi	15psi	60psi	135psi
0	3	186	> 5 Liters	> 5 Liters	10	10	6

Timing

Apply time was shown to be faster than the benchmark average for new virgin parts. However, the Release was slower than the benchmark average. Figures 6 and 7 show one run each of the Apply and Release time. The table below shows the results for each run:

Bus 512 FootValve								
Time (sec)								
3-Run Avg	Apply, 0-60psi				Release, 95-5psi			
	Pri		Sec		Pri		Sec	
	Left	Right	Left	Right	Left	Right	Left	Right
Run 1	0.161	0.160	0.168	0.168	0.474	0.475	0.523	0.517
Run 2	0.163	0.161	0.169	0.169	0.476	0.475	0.521	0.518
Run 3	0.162	0.160	0.168	0.168	0.475	0.469	0.511	0.515
Average	0.162	0.160	0.168	0.168	0.475	0.473	0.518	0.517
Benchmark	0.186		0.213		0.454		0.497	

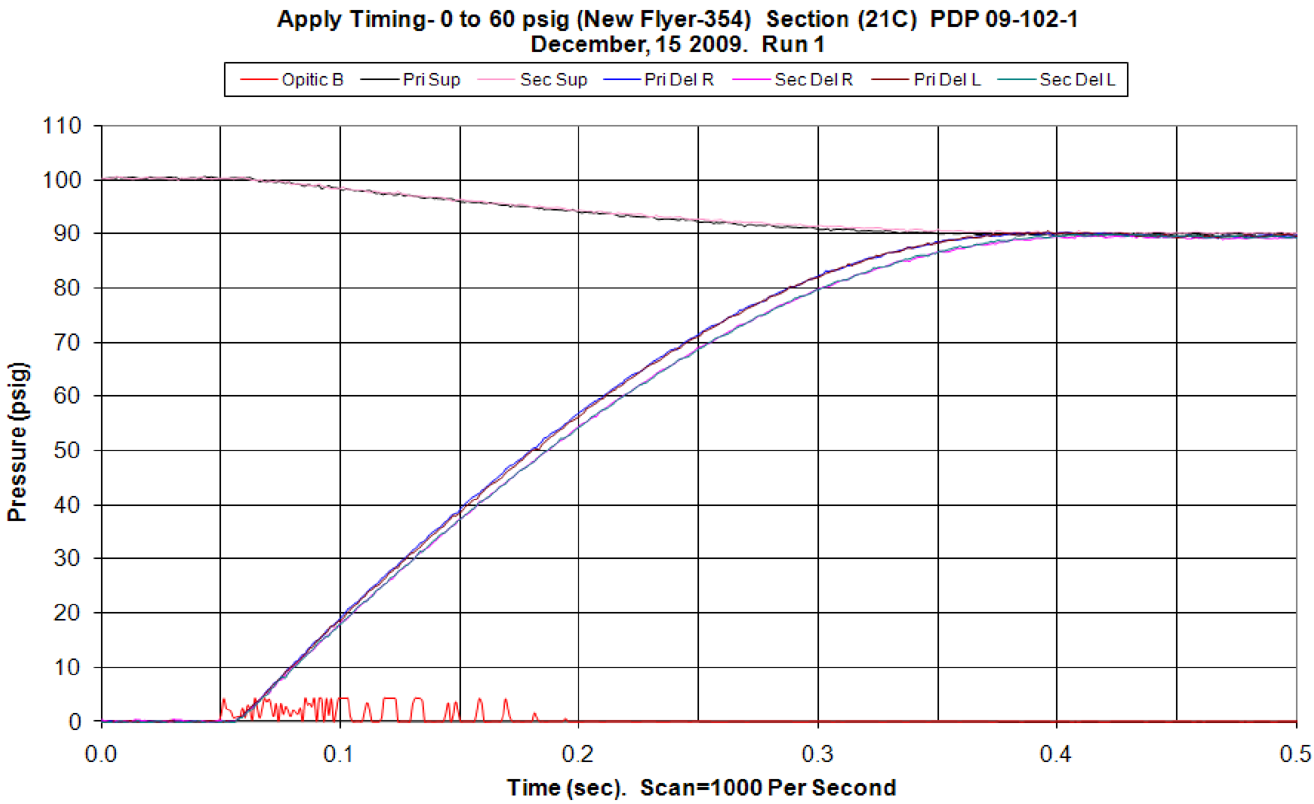


Figure 6: Foot Valve Apply Time

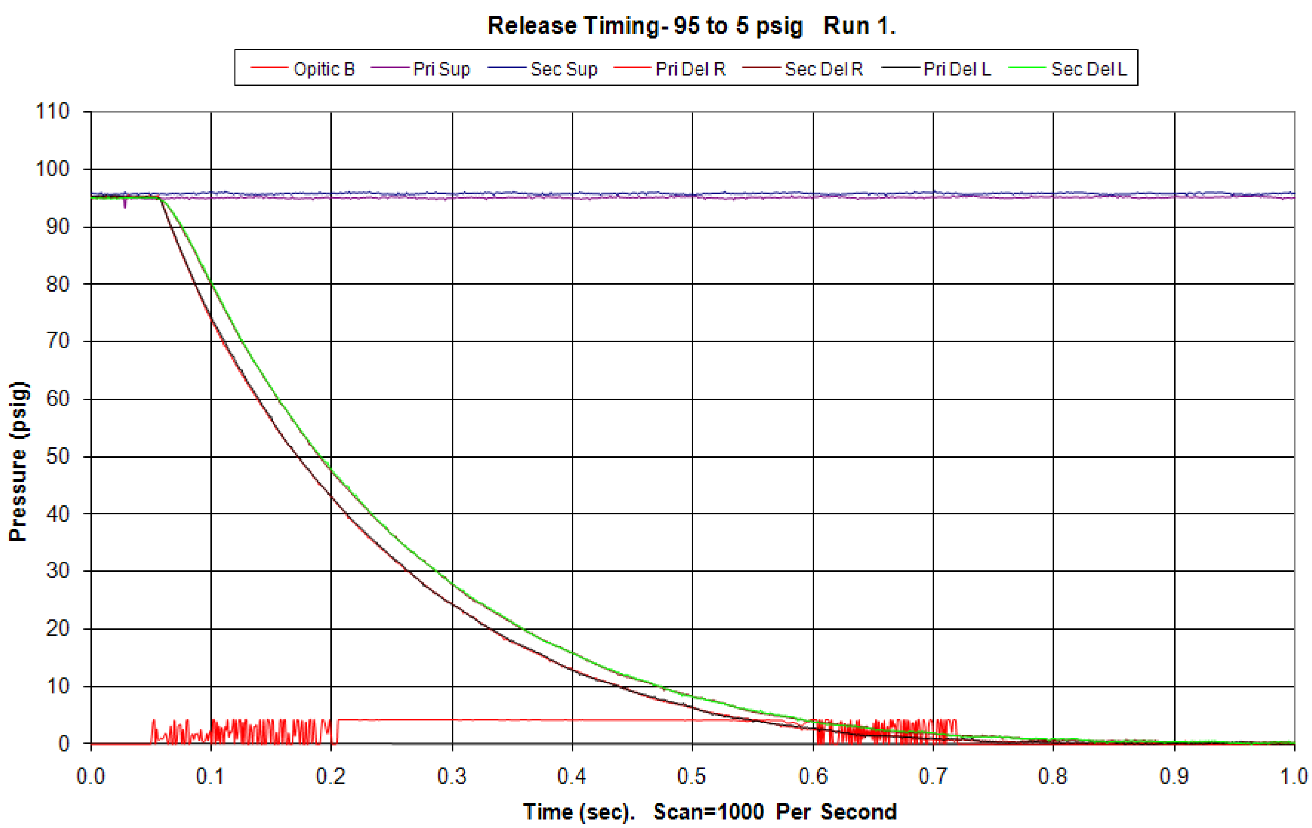


Figure 7: Foot Valve Release Time

Input/Output

Input/output testing was then performed to determine if any anomalies occur in performance. The following table highlights some performance characteristics taken from the valve compared to benchmark averages of new virgin parts:

Bus 512 Input/Output Performance		
Characteristic	[redacted]512	Benchmark
Travel @ Start Of Primary Delivery (in)	0.122	0.089
Force @ Start of Primary Delivery (lbf)	63.4	54.9
Secondary Crack @ 2-PSIG of Secondary Delivery (Primary-Secondary) (psig)	6.0	4.2
Primary Histeresis @ 0.200" of Travel (psig)	13.2	11.9
Travel @ 0-PSIG of Primary Del (in)	0.024	0.058
Secondary @ 0-PSIG of Primary Del (psig)	1.9	2.2
Travel @ 0-PSIG of Secondary Del (in)	0.009	0.020
Force @ 0-PSIG of Secondary Del (lbf)	0.7	6.7

The valve showed reduced performance on release, indicated by reduced travel and force available at full release (0psi Secondary) than the benchmark average. Figure 14 shows the delayed release in the secondary circuit. Note that the benchmark valves had a 3psi crack pressure setting vs. 6psi measured on the valve removed from bus 512, as shown in Figure 12. Figures 8-15 below illustrate the performance of the foot valve:

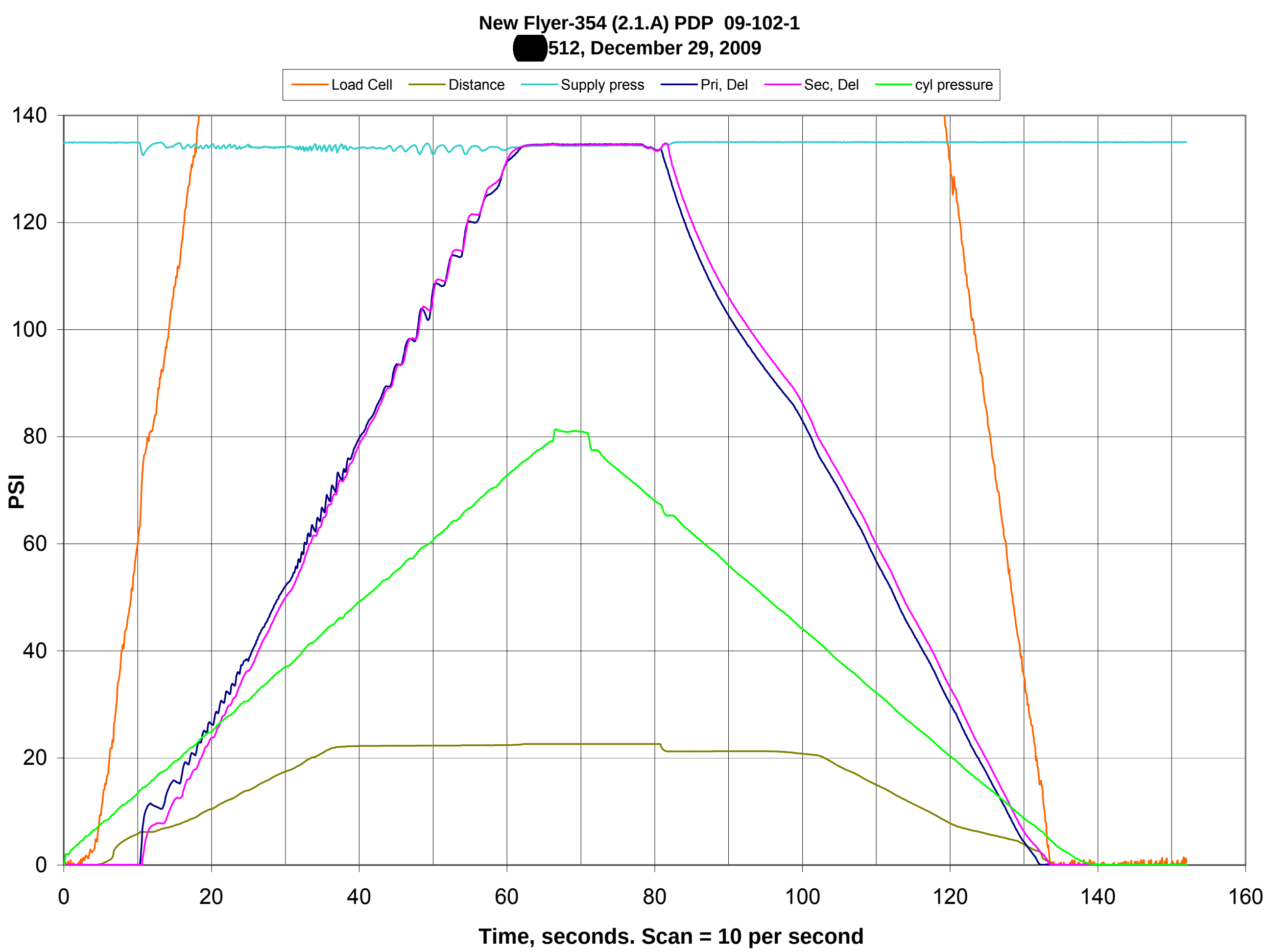


Figure 8: Pressure, Force and Travel vs. Time

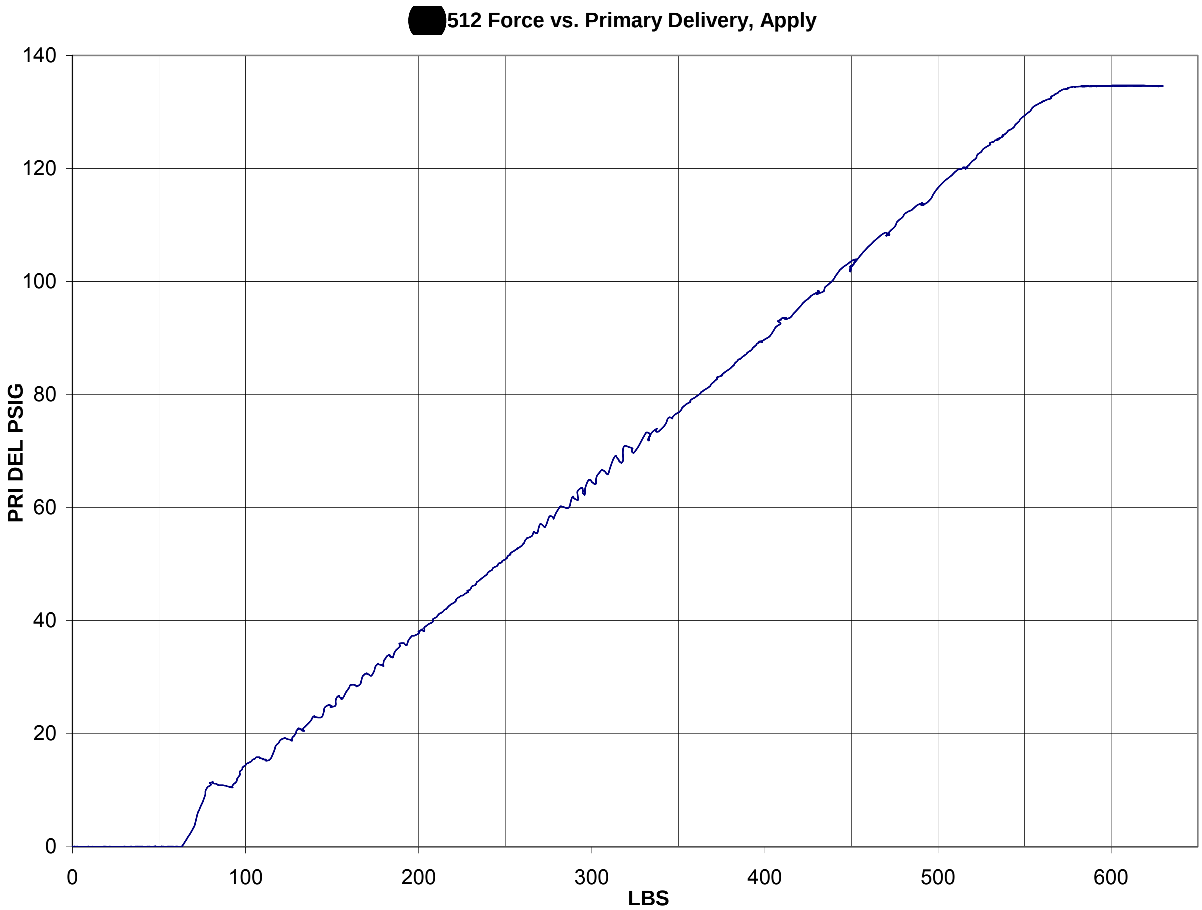


Figure 9: Primary Delivery Pressure vs. Plunger Force, Apply

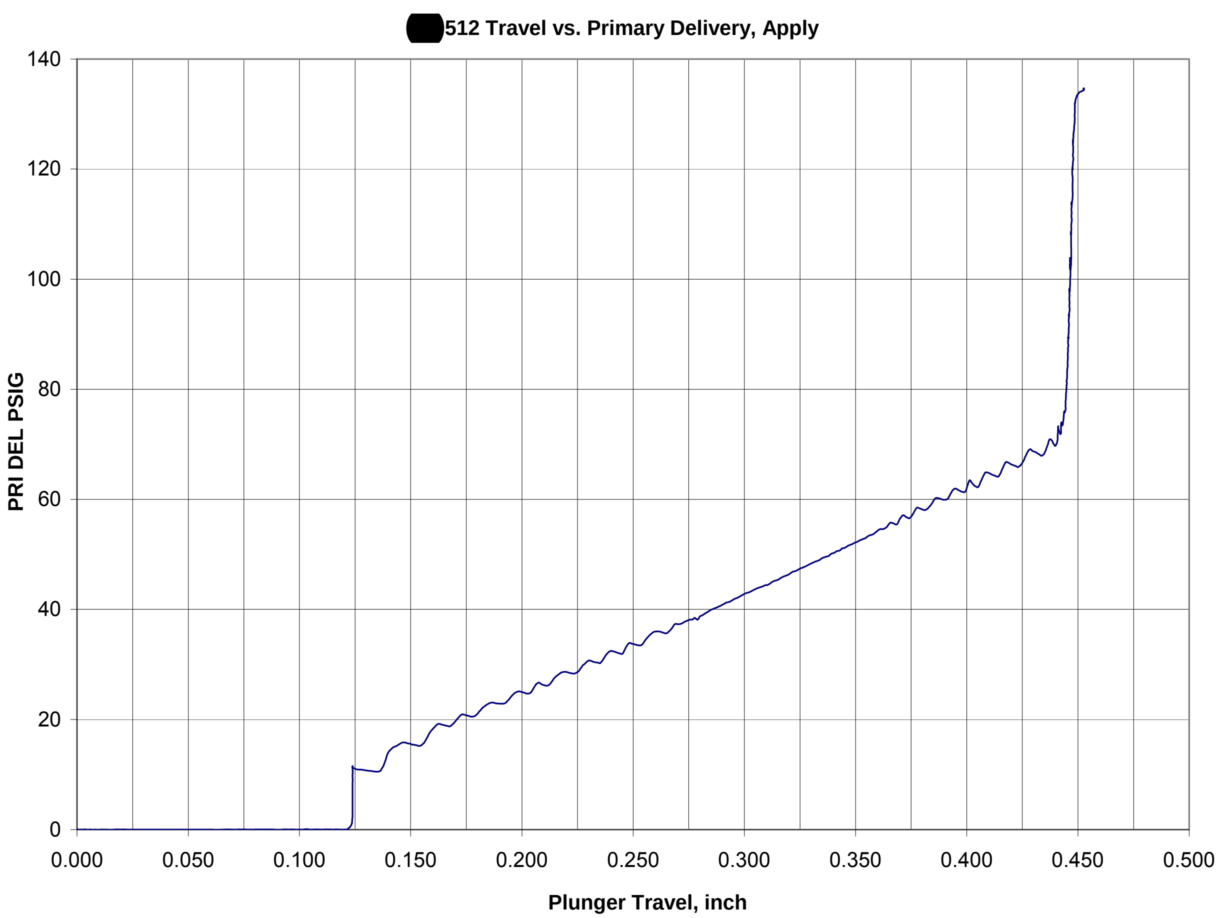


Figure 10: Primary Delivery Pressure vs. Plunger Travel, Apply

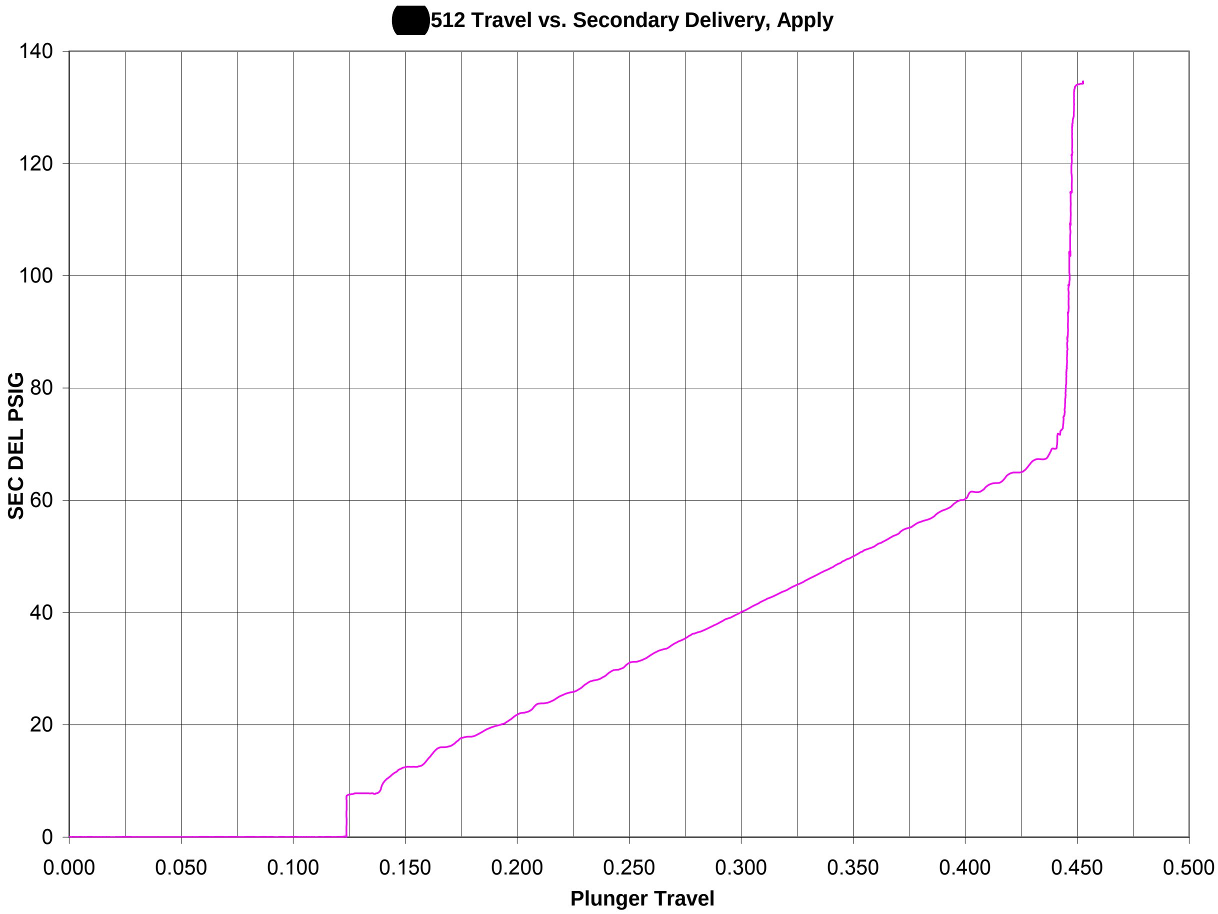


Figure 11: Secondary Delivery vs. Plunger Travel, Apply

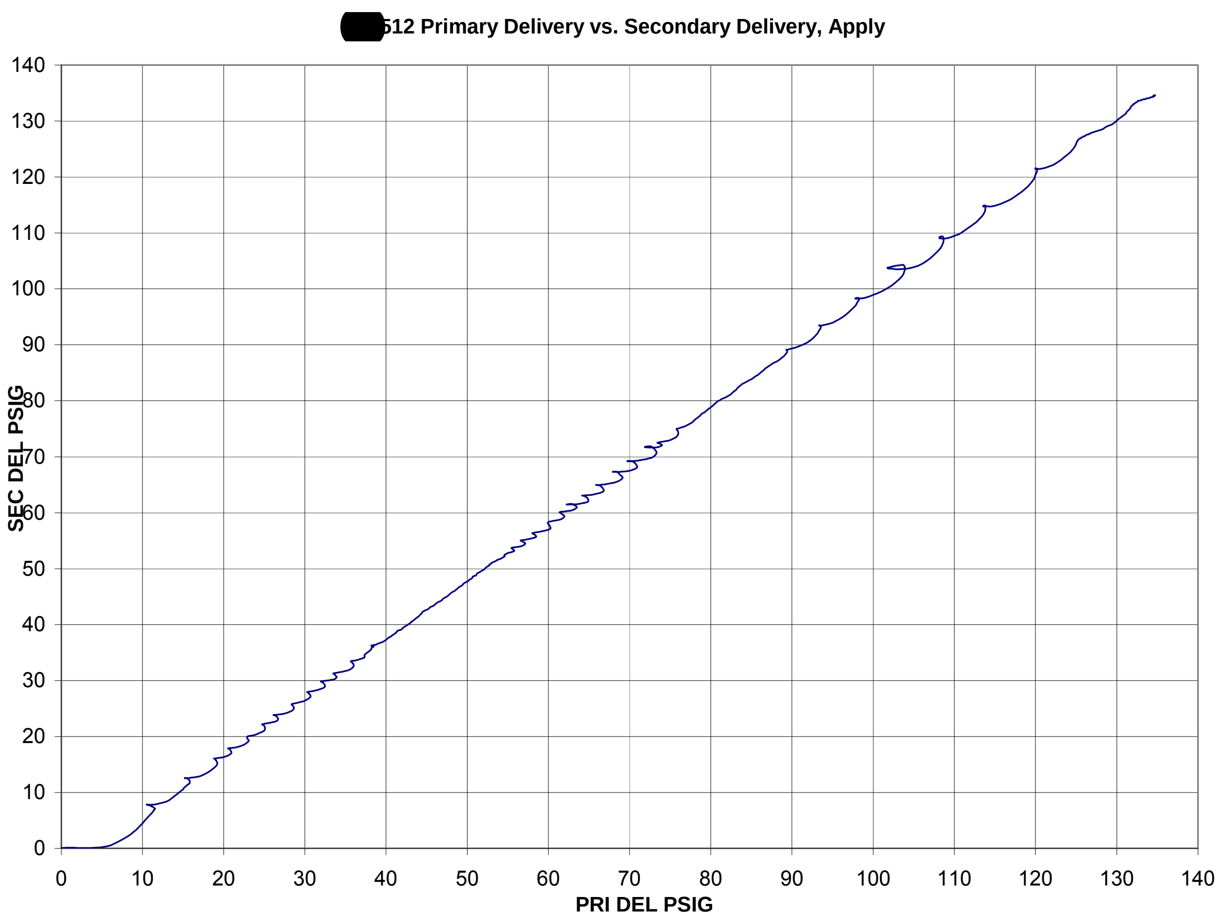


Figure 12: Secondary Delivery Pressure vs. Primary Delivery Pressure, Apply

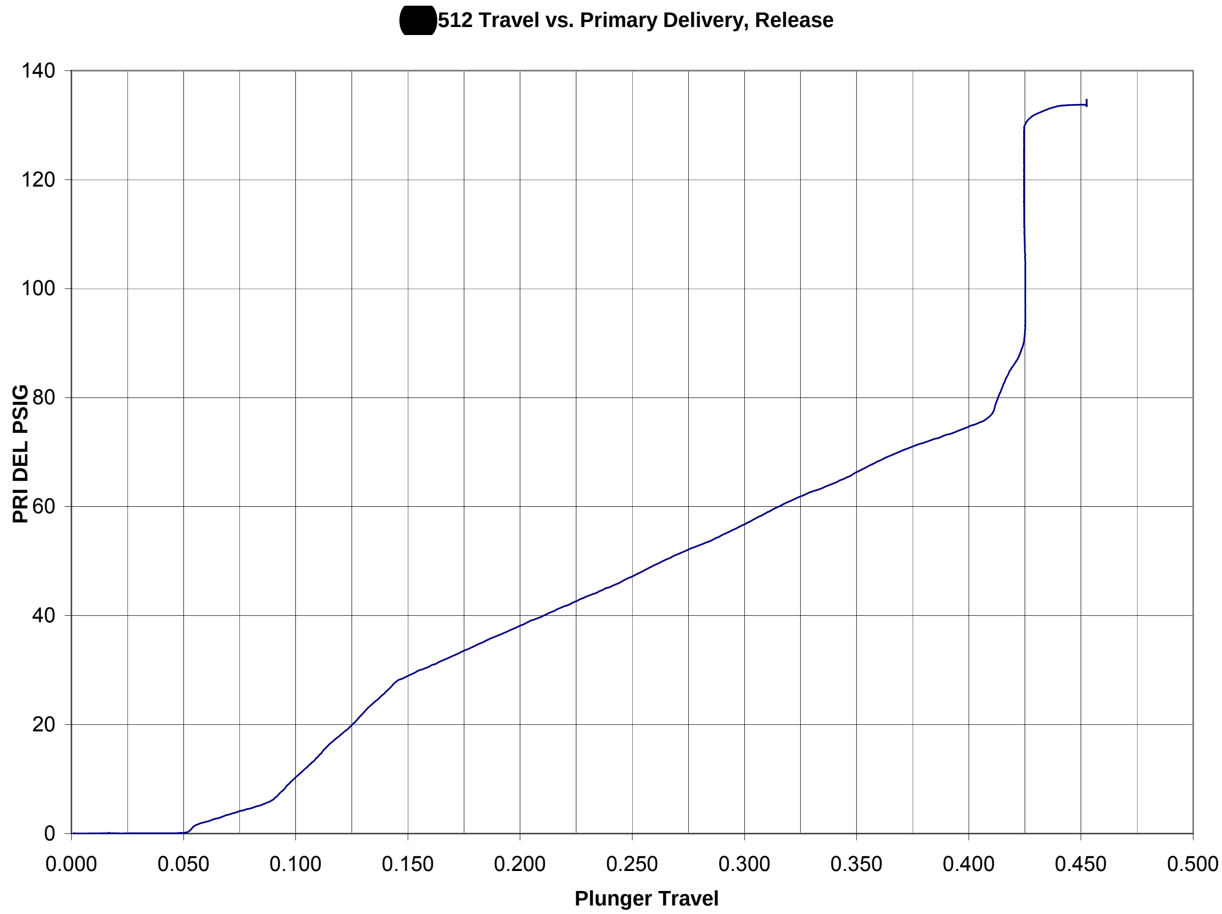


Figure 13: Primary Delivery Pressure vs. Plunger Travel, Release

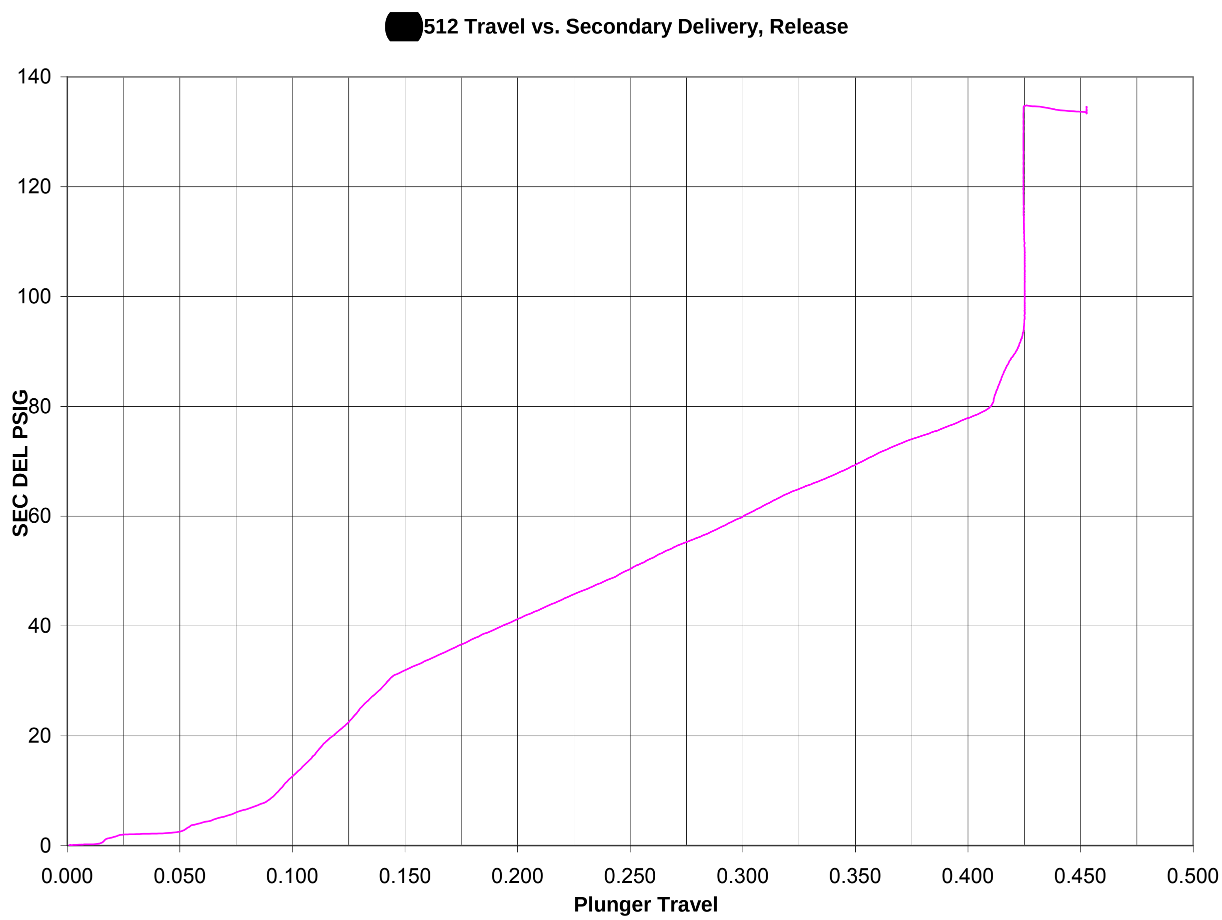


Figure 14: Secondary Delivery Pressure vs. Plunger Travel, Release

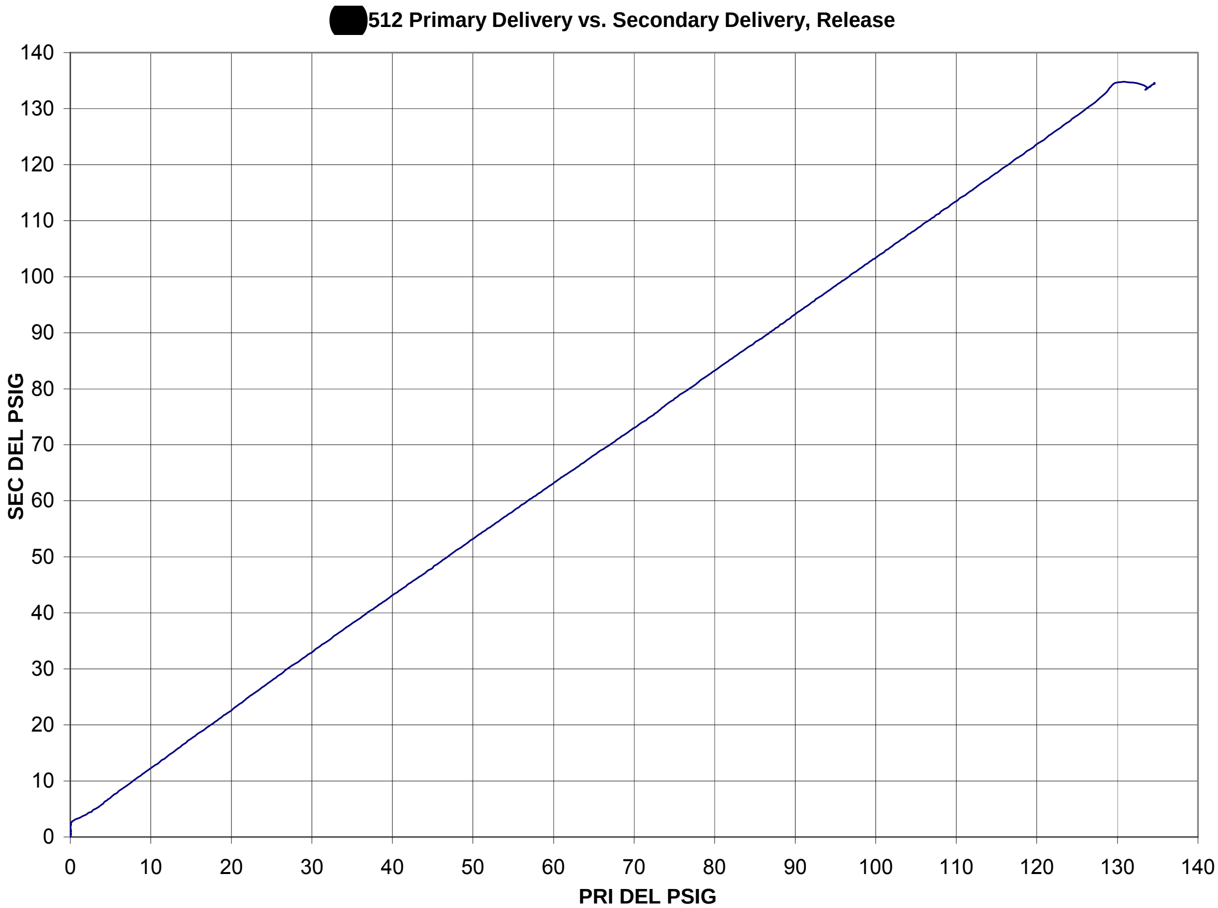
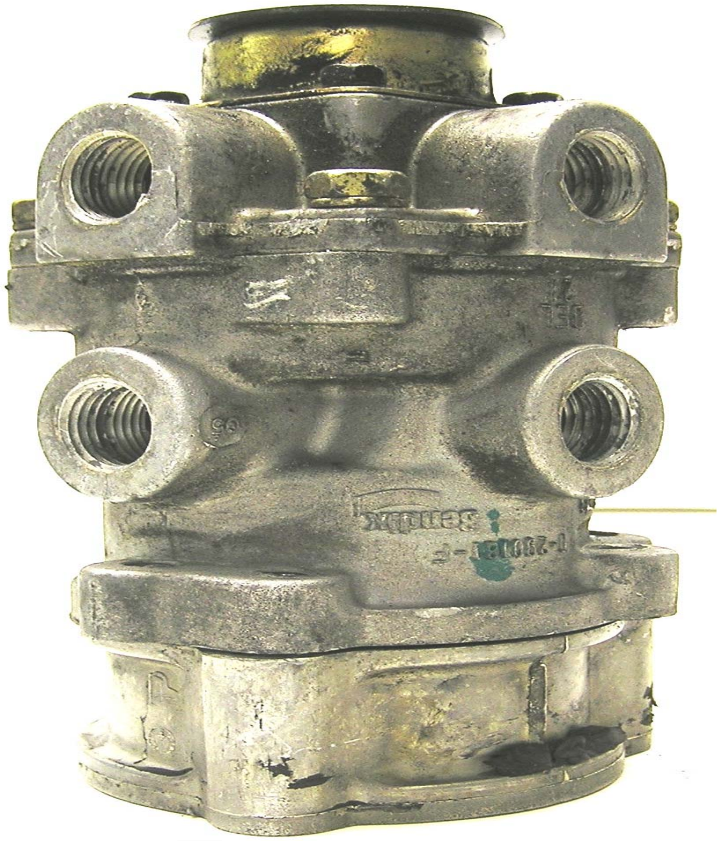


Figure 15: Secondary Delivery Pressure vs. Primary Delivery Pressure, Release

Teardown Inspection

It was discovered that the O-ring seal between the primary body and steel spring adapter had been cut, resulting in a leakage path from the primary supply cavity to atmosphere. The valve showed a moderate amount of liquid oil contamination on both the primary and secondary pistons and in both delivery cavities. Both inlet/exhaust seals appeared to show some wear at the seat contact points. The following pictures illustrate the condition of the internal seals and cavities:



[redacted]512 E-10P Foot Valve

Steel Spring Adapter & Cut O-Ring

Steel Spring Adapter & Cut O-Ring

Cut O-Ring

Steel Spring Adapter Assembly – Retainer Ring & Plunger Cap Removed

Plunger Cap, Steel Spring & Retainer Ring

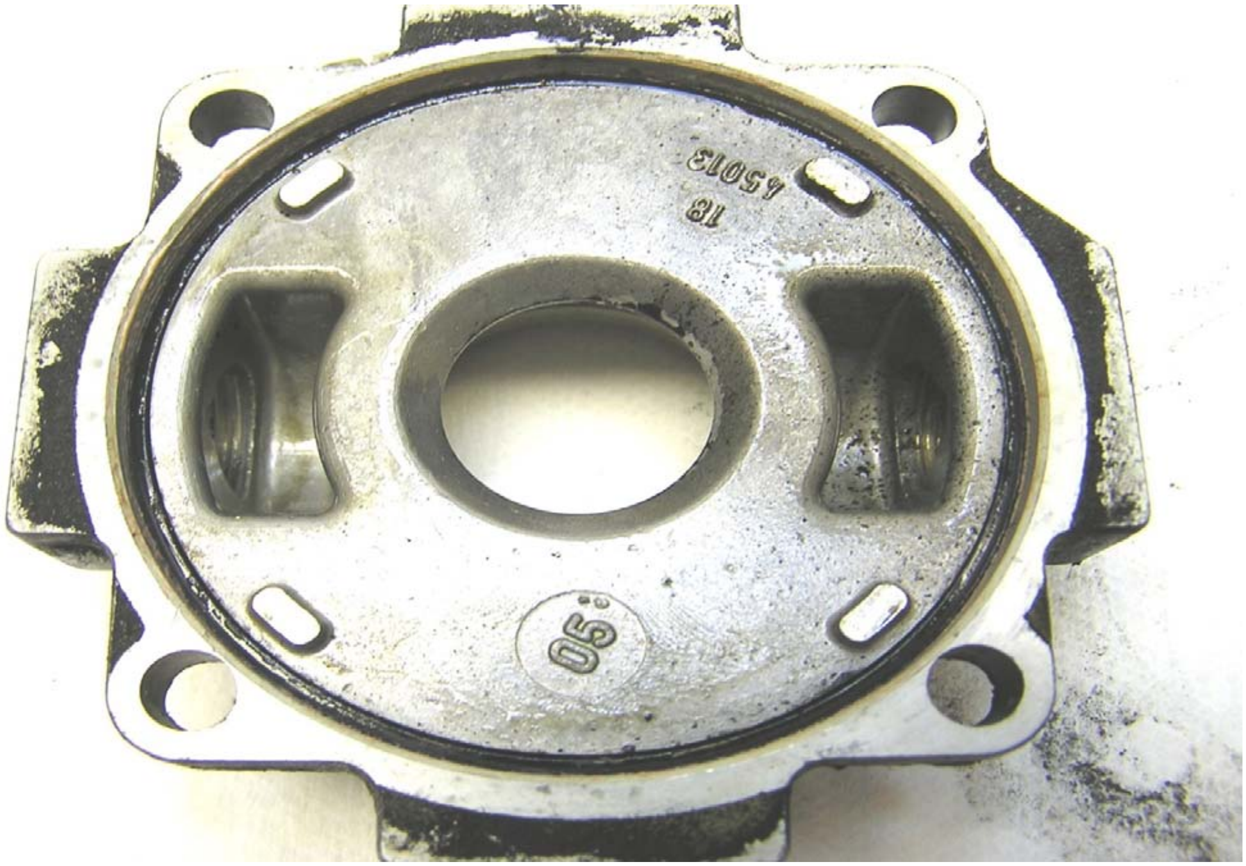
Top Side of Primary Piston

Primary Piston Underside with Springs & Adapter Body

Primary Body Cavity with Primary Inlet/Exhaust Seal

Primary Inlet/Exhaust Seal

Secondary Piston Underside



Secondary Delivery Cavity

Secondary Inlet/Exhaust Seal

The foot valve was then forwarded to the Materials Engineering laboratory to check for changes in seal hardness and the presence of chemical contamination in the internal valve cavities. Seal hardness was tested using a Wallace microhardness tester. The results were reported in degrees IRHD. The seal hardness was compared to measurements on like seals removed from a virgin unused valve. The Secondary piston o-ring appeared to be most affected with a difference of -10°IRHD over a virgin o-ring. A chemical wash of the internal valve cavities showed a similar contaminant found in the bus 501 relay valve results and other previous relay valve tests. The table below summarizes the findings:

Bus 512 Foot Valve		
Seal	Seal Δdu	Contamination Present (Y/N)
Primary Inlet/Exhaust	-3	Y
Primary Piston O-Ring	-5	
Secondary InletExhaust	4	
Secondary Piston O-Ring	-10	

Refer to ArvinMeritor Laboratory Service Request 31293-5 for details.

ArvinMeritor

REQUEST NUMBER	31293-5
PROJECT NUMBER	RWNP0299
REPORT DATE	26 April 2010

MATERIALS ENGINEERING

ANALYSIS OF VARIOUS SAMPLES FROM TWO BUSES:

PART NUMBERS:

MODELS:

PLANTS/SUPPLIERS:

CUSTOMERS:

New Flyer

REFERENCE REPORTS:

31406-1 31293-6

ABSTRACT:

Twenty parts or samples from buses were submitted for analysis. It was requested that these samples be analyzed to measure the identity and, where feasible, the quantity of contaminants present. Polysiloxane (likely silicone oil or grease) was found in foot valve and air dryer components. Hydrocarbon contamination (see Report 31293-6) was found in exhaust and air dryer support hardware. The cooling coil debris from Bus 512 contained 32 wt.% organic contamination.

KEY WORDS:

Field Return Elastomer Contaminant

Infrared

REQUESTED BY: J. Paoletti

TOTAL COST $ 1300

DISTRIBUTION:

K. Yu M. Hartry

PREPARED BY:

Bruce F. McGlone

INTRODUCTION

Twenty parts or samples from buses) were submitted to Materials Engineering for analysis. It was requested that these samples be analyzed to measure the identity and, where feasible, the quantity of contaminants present.

COMMENTS

Samples include:

- various swabs
- air tank samples
- air dryer
- foot valve
- oil separator fittings
- muffler tank
- compressor cooling coil debris
- air dryer desiccant bed
- steering knuckle lube

It should also be noted that several of the submitted sample containers were empty.

Where needed, cavities were individually extracted with HPLC-grade hexane as follows:

1. Cavity washed with [3 X ~10 ml] of solvent. All solvent extracts from each valve were individually captured in clean beakers.
2. Solvent extracts were evaporated to ~2 ml.
3. Infrared data on each solvent extract were obtained through the use of a ZnSe cell and Horizontally Attenuated Total Reflectance hardware. Solvent extracts were evaporated on a blanked ZnSe cell.

CONCLUSIONS

<u>Sample swabs (1-1, 1-2, 1-3, 2-1, 2-2, see **DATA**):</u>

A trace level of polysiloxane (likely silicone oil or grease) contamination was seen in Bus 501 foot valve exhaust. A trace level of hydrocarbon contamination (referenced in Report 31293-6) was seen in Bus 512 "consep exhaust".

<u>Bus 501 air dryer support hardware (6-1, 6-2, 6-3, **DATA**):</u>

All of these samples contained polysiloxane (likely silicone oil) contamination. A trace level of hydrocarbon contamination (as referenced in Report 31293-6) was seen in 6-2 and 6-3.

<u>Bus 512 copper cooling coil debris (2-5, **DATA**):</u>

This brown debris sample contained 32 wt.% organic contamination, which was not analyzed further.

<u>Oil samples:</u>

Infrared analyses of the conventional 500-series oil and the synthetic 700-series oil indicate that they are very similar, with no unusual contamination.

<u>Air Dryers:</u>

The new and used air dryers could not be solvent-extracted or disassembled.

DATA

	Sample No.	Silicone contaminant?	1739 cm-1 hydrocarbon contaminant?	Other IR data (cm-1)
501:				
foot valve exhaust swabs	1-1	trace	No	802
steering lube swabs	1-2	No	No	1580
A/D discharge swabs	1-3	No	No	No
crankcase oil	1-4	No	No	No
tank purge solids (small sample)	1-5	Insuff. Sample	Insuff. Sample	Insuff. Sample
brass oil separator fittings	1-6	No	Trace	No
501 CRT 2000 Used Air Dryer (and grey hardware)	6	Cannot wash dryers - hexane solvent will not gravity drain. Cannot disassemble them.		
Thinner 2-port part: Straight through air passage fed from within at mid-point	6-1	trace	No	802
Thicker 2-port part; Irreg passage. Electrical port on exterior.	6-2	Yes	Trace	802
Gasket	6-3	Yes	Trace	802
501 PNG (?) tank (small black tank)	4	No	No	No
512:				
foot valve exhaust swabs	2-1	No	No	802, 1538
consep exhaust (?) swabs	2-2	No	trace	No
crankcase oil	2-3	No	No	No
wet tank oil (small sample)	2-4	No	No	No
Cu cooling coil debris coating	2-5	31.9% Organics	31.9% Organics	= = = = =
Additional samples:				
Conventional oil sample: 500 series	3-1	No	No	Similar to 3-2
Synthetic oil sample: 700 series	3-2	No	No	Similar to 3-1
Virgin swabs (reference)	3-3	Nothing...	Nothing...	Nothing...
New Air Dryer	5a	Cannot wash dryers - hexane solvent will not gravity drain. Cannot disassemble them.		

ArvinMeritor

REQUEST NUMBER 31293-6
PROJECT NUMBER RWNP0299
REPORT DATE 21 January 2010

MATERIALS ENGINEERING

ANALYSIS OF USED VALVES:

PART NUMBERS:

MODELS:

PLANTS/SUPPLIERS:

CUSTOMERS:
New Flyer

REFERENCE REPORTS:
31406-1 31293-5

ABSTRACT:

One used Haldex relay valve and one used Bendix E10 foot valve were submitted to Materials Engineering for analysis. Measurements of the microhardnesses of the elastomeric components, internal solvent wash of the valves and evaluation of semi-solid black deposits were requested. The customer is The modulator seal from Unit 501 was excessively soft. Polysiloxane (likely silicone oil) was noted in both parts, along with a trace level of an organic contaminant previously found in several other Meritor-WABCO components. The silicone component should be compatible with the elastomers used in relay valves; its source could be silicone grease or DOT5 brake fluid. The small deposits visible on metallic surfaces of both parts appear to be thermally-oxidized hydrocarbons.

KEY WORDS:
Field Return, Elastomer, Contaminant, Infrared

REQUESTED BY: J. Paoletti

TOTAL COST $ 700

DISTRIBUTION:
K. Yu
M. Hartry

PREPARED BY:
Bruce F. McGlone

DATA

Sample 1: Unit 501 Relay Valve

	Wallace Microhardness[1] (deg.)	Change in Microhardness (deg.)
Modulator Seal	38	-32
Exhaust Seal	53	-6

Cavity Wash with hexane
IR data interpretation:

Trace level of h'carbon component at ~1740 cm-1
Siloxane: Yes.
Similar to 2 below

Sample 2: Unit 512 Foot Valve

Labeled As:	Wallace Microhardness[1] (deg.)	Change in Microhardness (deg.)
Exhaust Diaphragm	72	No reference data
Primary Modulation Tube	59	No reference data
Secondary Modulation Tube	66	No reference data
Primary O-Ring	63	No reference data
Secondary O-Ring	60	No reference data

Cavity Wash with hexane
IR data interpretation:

Trace level of h'carbon component at ~1740 cm-1
Siloxane: Yes.
Similar to 1 above

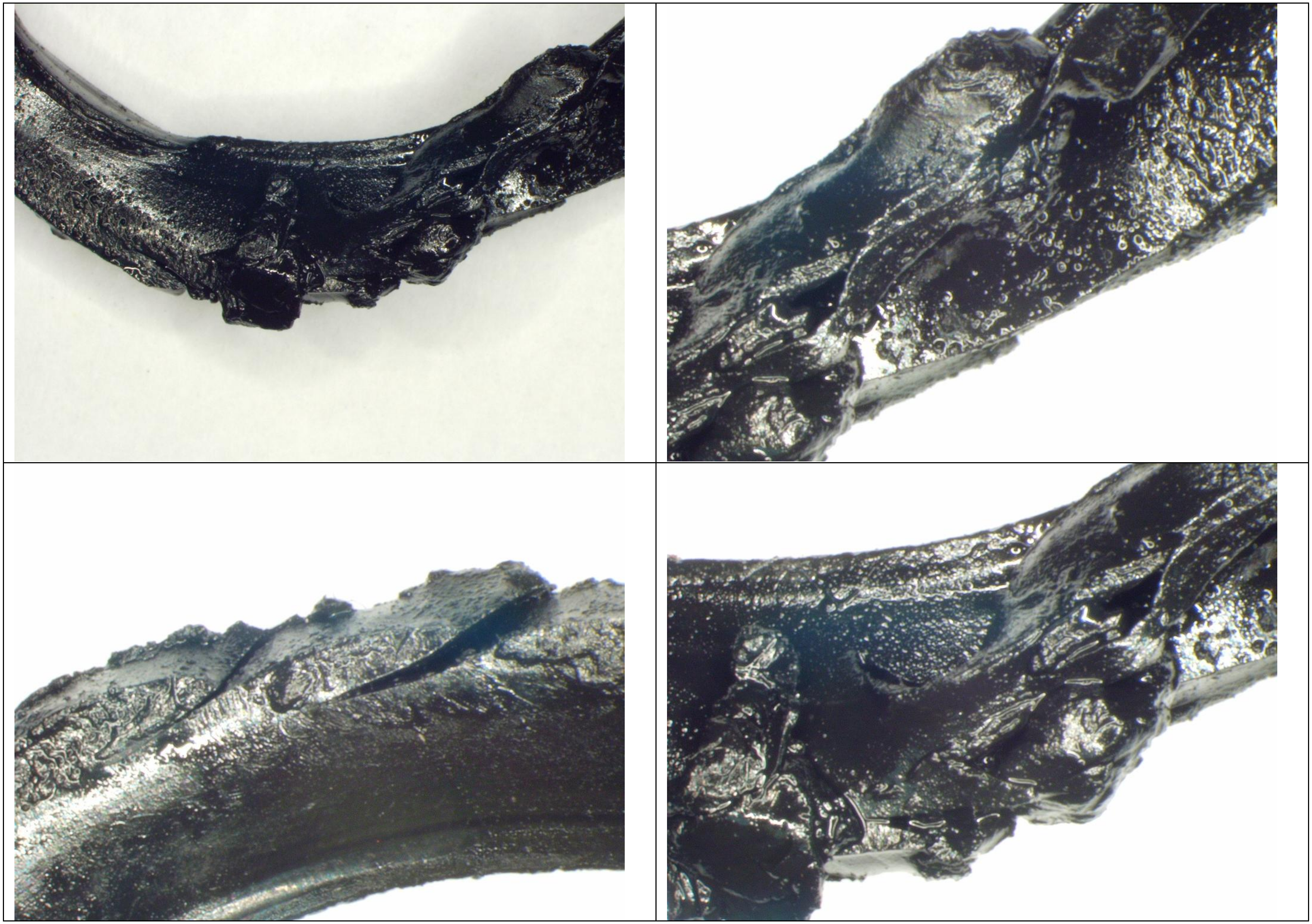
1: Wallace microhardness measurements were acquired per ASTM D1415.

[redacted] – New Flyer relay valve seals

#502 Date code 077A5K

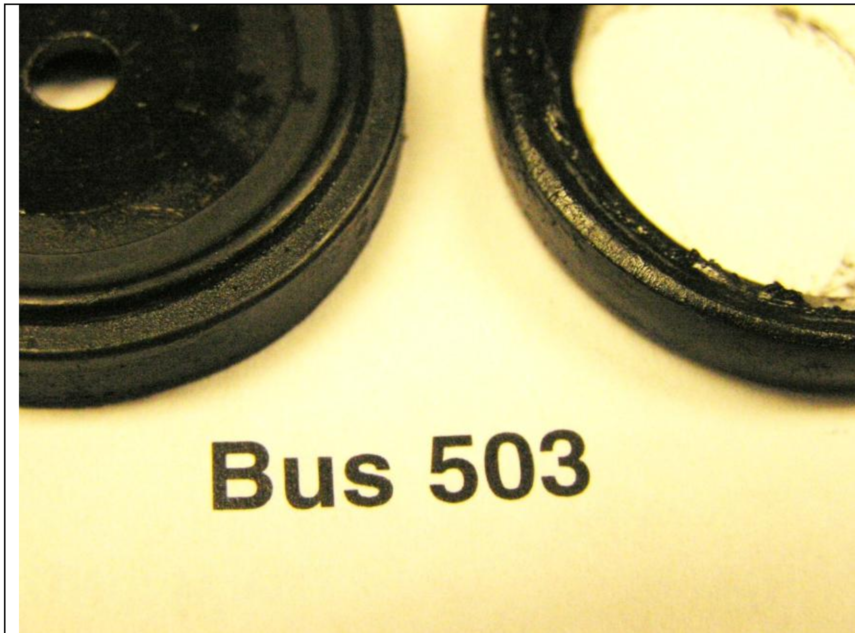
[redacted]– New Flyer relay valve seals

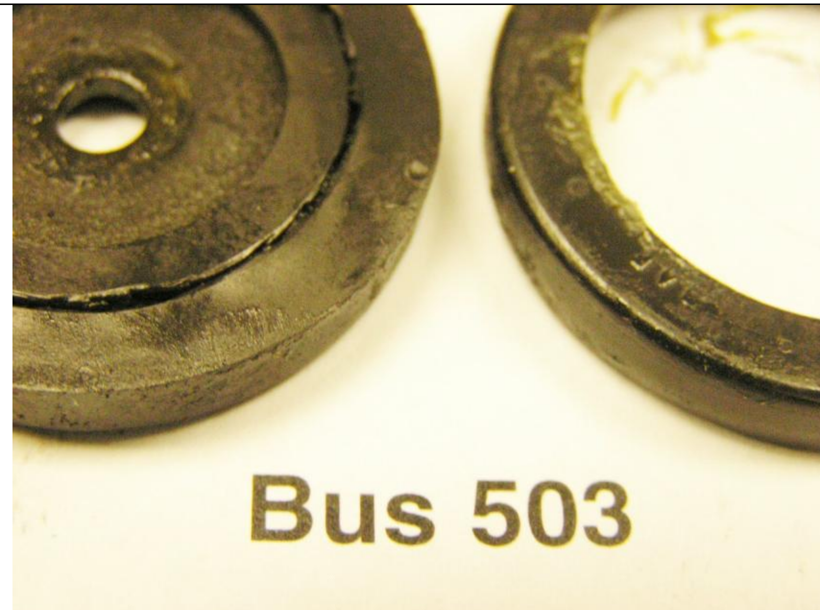
#502   Date code 077A5K

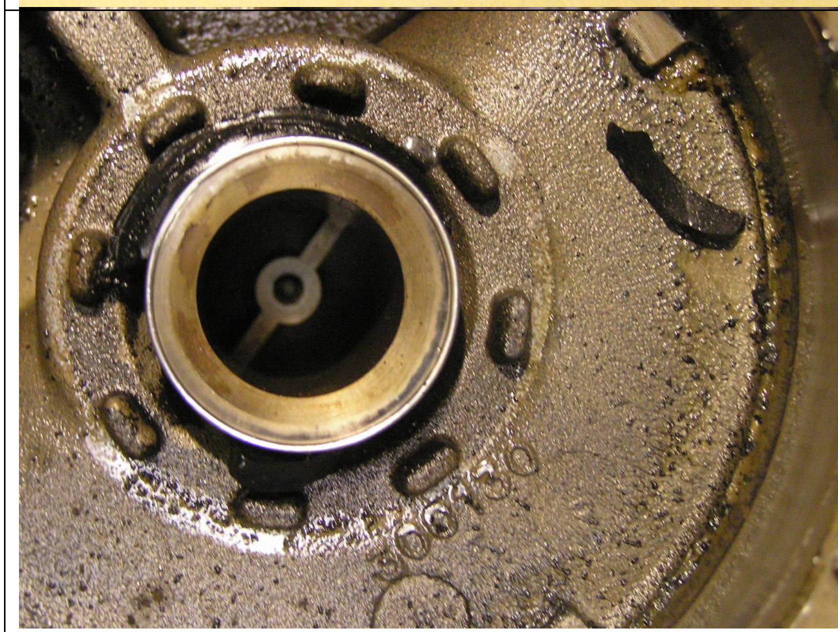


[redacted] – New Flyer relay valve seals

503 Date code 077A5K

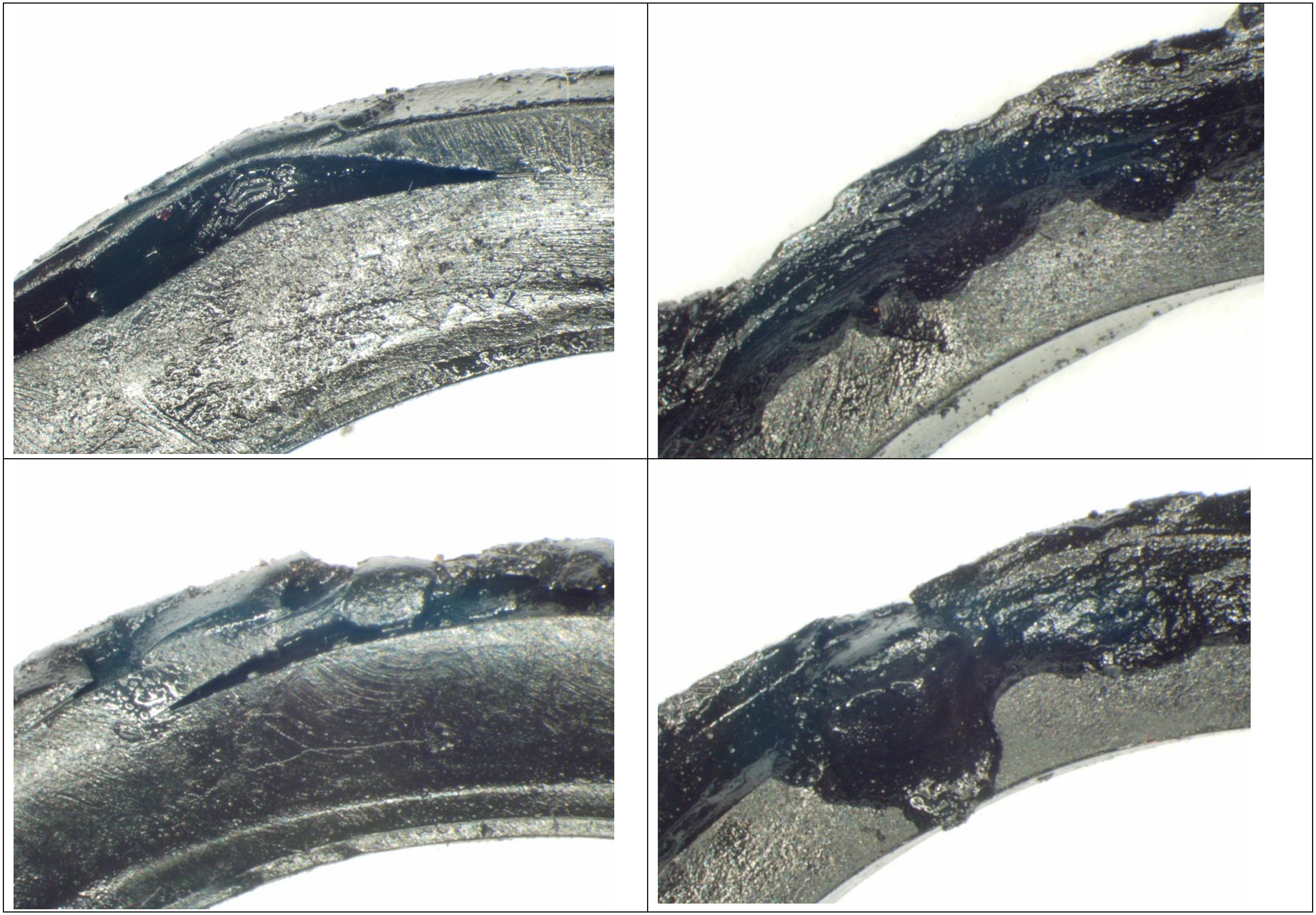






[redacted] – New Flyer relay valve seals

503 Date code 077A5K



[redacted] – New Flyer relay valve seals

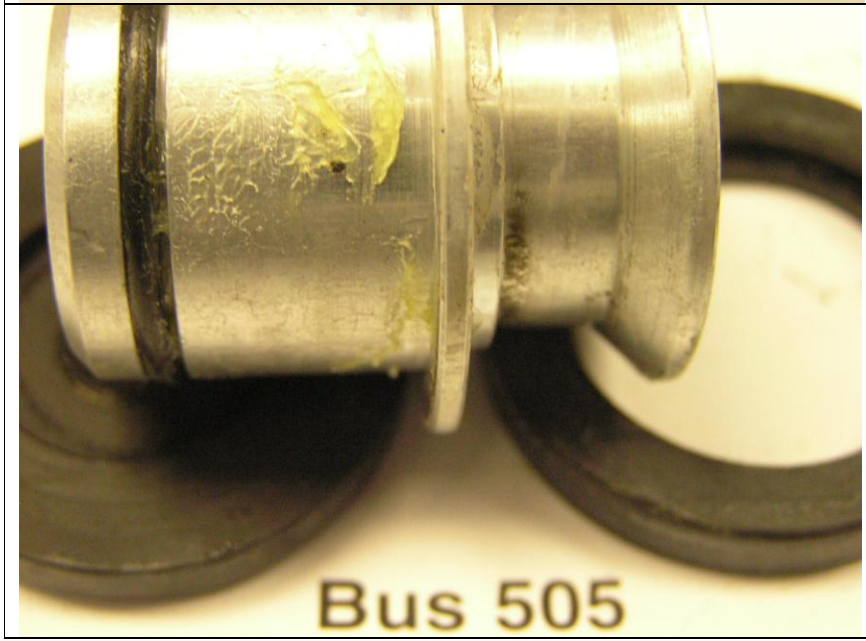
\504 Date code 077A5K

[redacted] – New Flyer relay valve seals

504 Date code 077A5K

[redacted] – New Flyer relay valve seals

505 Date code 041A9K

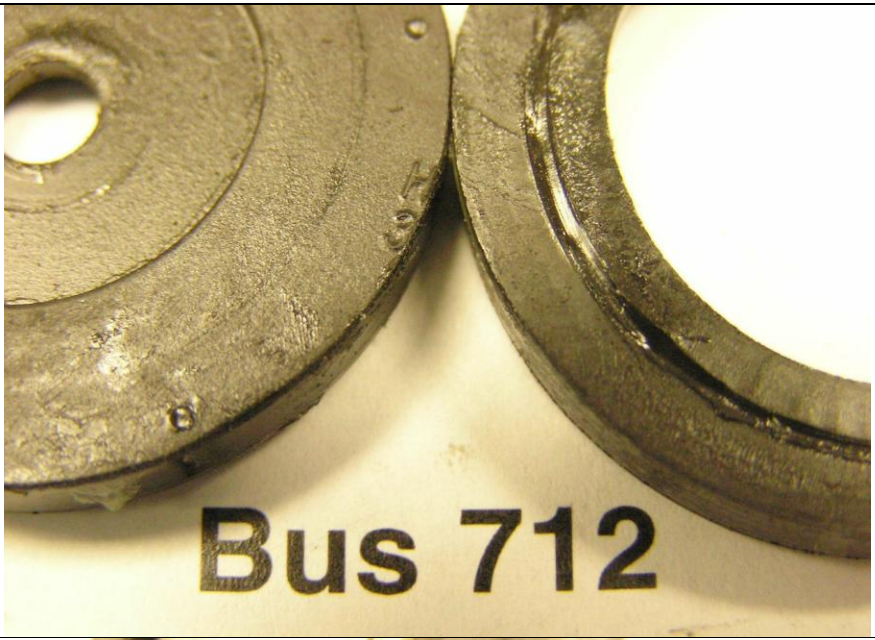


[redacted]– New Flyer relay valve seals

711 Date code 0401A9K

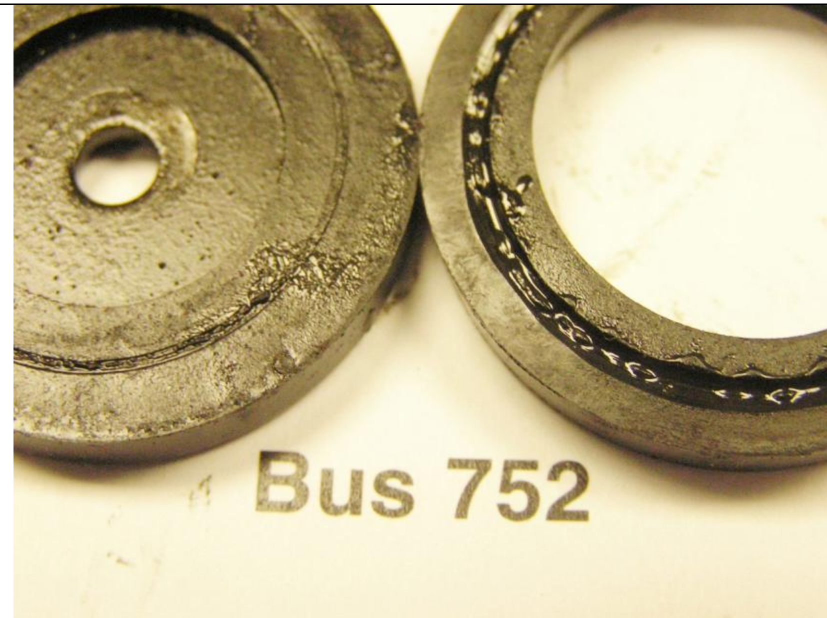
[redacted] – New Flyer relay valve seals

712 Date code 0401A9K



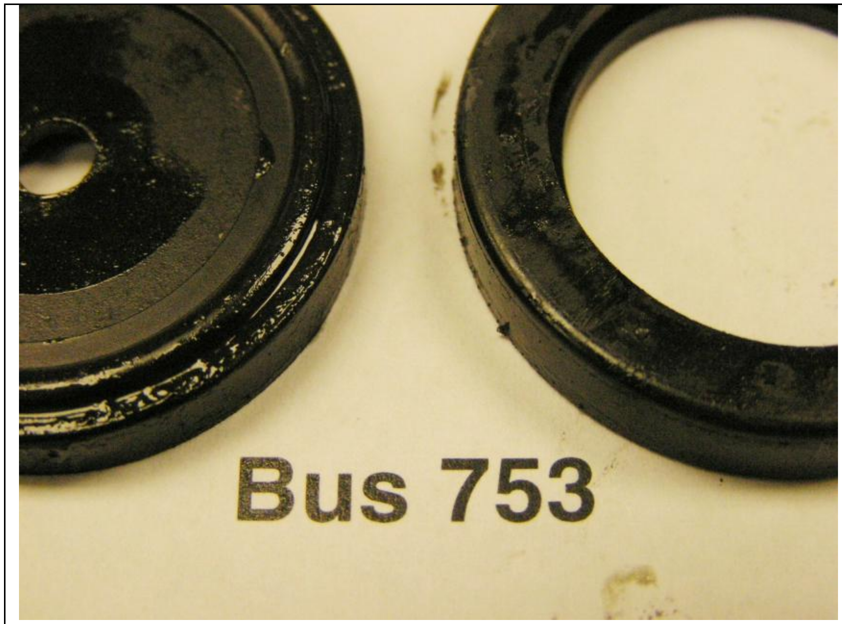
[redacted]– New Flyer relay valve seals

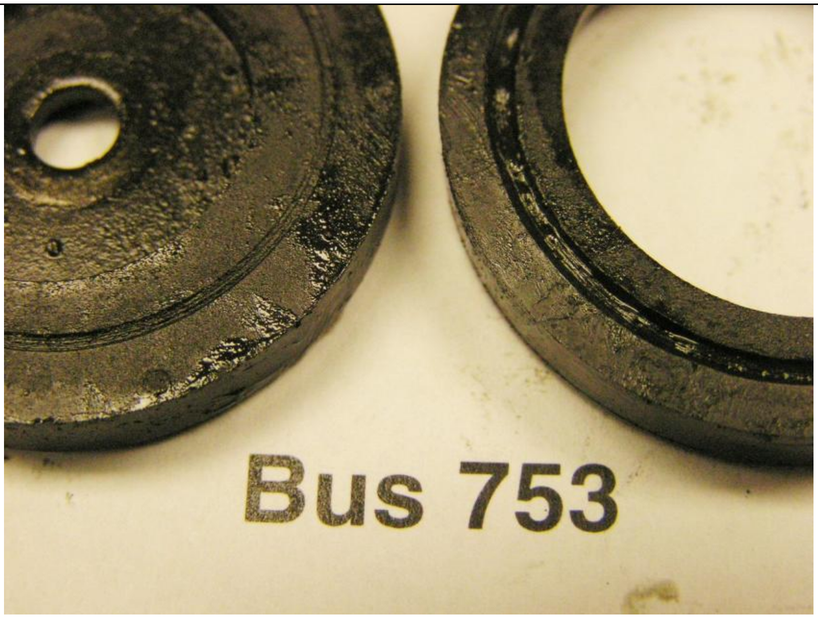
752 Date code 204A7K



[redacted] – New Flyer relay valve seals

753 Date code 204A7K





Closing Report – EA09-010

Air-Actuated Rear Brake Control Valves Manufactured by Haldex Brake Products Corporation, Distributed by Meritor WABCO Vehicle Control Systems, And installed in Vehicles Manufactured by New Flyer Industries, Ltd.

CONTENTS

(9) Appendices (continued)

Appendix A - New Flyer Summary dated October 21, 2010

Appendix B - Meritor WABCO Summary

Appendix B, Attachment A - Summary of Meritor WABCO Inspections of Valves Removed from Service

Appendix B, Attachment B - Parker Hannifin Summary of Inspections of Brake Tubing Materials Removed from Service

Appendix B, Attachment C - Meritor WABCO Summary of Inspections and Testing of Valves Removed from Service

Appendix B, Attachment D -Arvin Meritor Summary of Examination of Contamination Samples Removed from Service

Appendix B, Attachment E – Arvin Meritor Summary of Examinations of Valve Seal Materials Removed from Service

Appendix B, Attachment F, Photographs depicting the Condition of Valve Seals Removed From Service

Appendix C - ODI Notes from October 27-28, 2009 Site Visit

(1) Subject Components -

This report summarizes the Office of Defects Investigation's (ODI's) investigation of air-actuated rear brake control valves manufactured by Haldex, distributed by Meritor WABCO, and purchased and installed in certain vehicles manufactured by New Flyer Industries, Ltd.

Photograph 1 – New replacement rear brake control valve shown in the as-installed position in a vehicle evaluated at a northeast transit bus operation. New valve assemblies were installed so that the previously-installed valves could be removed and inspected at the manufacturers' laboratories as part of this investigation. Source: ODI photograph taken at site visit, October 27-28, 2009.

ODI conducted this investigation in conjunction with EA09-009, Air Brake System Control Valves Installed in Mack model year 2005-2009, vehicle models CTP, CV, CNX, CXU, GU, LE, and MR. Both investigations address the same, or equivalent, valve assemblies but differ with respect to final vehicle manufacturer, installation and filtration parameters, and the characteristics of the vehicle application.

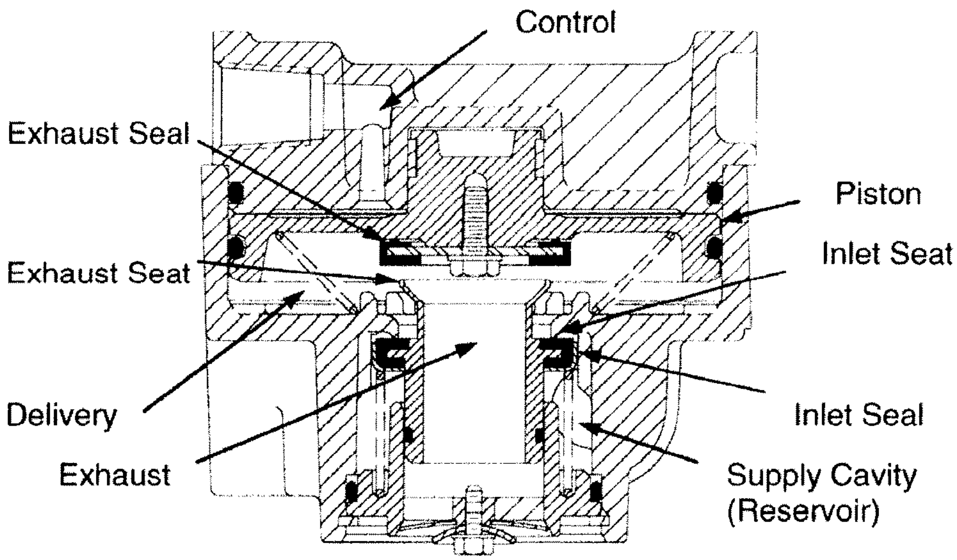
ODI closed EA09-009 on August 13, 2010, with the finding that the "investigation has not identified a defect [and] complaints have abated." ODI has made similar findings in EA09-010.

The vehicle parameters associated with current investigation EA09-010 which pertains to transit busses likely differ from the application parameters of heavy trucks investigated in EA09-009 in that

(a) The brake control valve is likely operated more frequently due to frequent stopping requirements inherent to the transit bus application;
(b) The volume of compressed air consumed in the transit bus application is likely generally greater than that of a heavy truck due to frequent vehicle stopping requirements and the greater use of other on-board air-actuated components such as windshield wipers and passenger doors; and
(c) The brake system air lines in transit busses are likely longer (greater distance from the compressor-treadle valve to the air dryer and control valve) due to the more distant placement of these brake system components in a transit vehicle than a heavy truck.

The following summary provided by Meritor WABCO explains the design and function of the subject valve.

Technical Description – Relay Valve Function



Engineering Assembly Cross-Section Drawing of Representative Control Valve - Source: Attachment D, Meritor WABCO response to ODI's request for Information, EA09-009, dated November 21, 2008.

"Service relay valves receive a pneumatic control signal from the vehicle foot pedal valve. The valve is used to speed up the application and release of the primary circuit service brakes which are typically the rear brakes on trucks, tractors and buses. [Pressurized] Control air on top of the piston forces the piston down until the exhaust seal engages [contacts] the exhaust seat and closes the exhaust passage. Further travel will cause the inlet seal to separate [unseat] from the inlet seat and allow supply air to pass into the delivery cavity and to the brake chambers.

When the exhaust seal or inlet seal is degraded, "the opening of the inlet seal may be reduced. The reduced valve travel may restrict the rate at which air passes through the inlet opening" [resulting in slower application of the affected brakes].

(2) Failure Mode -

In the present investigation, evidence from field returned valves generally indicate a softening and/or cutting of the exhaust valve seat. Appendix B, Attachment F contains photographs of valve seals which had been returned and inspected as part of EA09-010.

(3) Characteristics and Issues -

Inspections of components and contamination samples collected during fieldwork were conducted at Meritor WABCO, Haldex, and Parker Hannifan. These examinations detected evidence of n-Butyl Benzene Sulfonamide (BBSA) on the surfaces of the affected field-returned air valve seals. BBSA is a "plasticizer" that is used to "soften" elastomeric materials.

BBSA does not constitute any portion of the chemical make-up of the internal seals nor any other element of the control valve. This suggests that the BBSA has been transferred onto the seals from another upstream source. A significant amount of investigation activity among the various affected manufacturers has been to determine the source of the BBSA and assess its effect.

While considerations have been given to engine oils and additives, biodiesel fuels (B5, B10, etc.), and upstream components of the air system, evidence indicates that the plastic (nylon) air brake lines are the most likely source of the transferred BBSA. The nylon air lines (manufactured by Parker Hannifin Corporation) require a plasticizer (softener) so that the otherwise rigid tubing is flexible for handling and installation.

According to the brake line supplier and supported by laboratory data (summarized in Appendix B, Attachment B), brake line tubing gradually loses BBSA over time and the rate of loss is accelerated by exposure to higher temperatures. Once the brake lines have been installed and anchored at the appropriate positions in the vehicle, there is little need for the air line to retain its flexibility characteristics and the loss of BBSA is of little significance to the integrity and/or function of the air line. However, it appears that BBSA that has been displaced from the inside surface of the brake tubing may be transferred downstream and deposited on downstream brake components such as the subject air control valve seals. (Though inconsequential to this investigation, BBSA is also released from the brake tubing to atmosphere from the outside surface of the brake tubing.)

In light of these findings/ positions, investigation focused on the whether there have been any significant changes in the air brake system and/ or vehicle environment and/or duty cycle that might be casual or contributory factors. This area of the investigation has tentatively concluded that vehicle demand for compressed air are likely higher suggesting that compressor run cycles (volume and temperatures) are likely higher than in the past --- and that lubricants, fuels and their additives have also evolved creating many difficult to assess contributing factors and combinations of factors.

Air valves are "wear-out" components which are likely to require replacement as a normal maintenance requirement after some period of field use.

Based on discussions with manufacturers and fleet maintenance personnel, ODI conjectures that worn valves and valve seals (and other components in the vehicle air brake system) are most frequently detected by audible air leaks. In most cases, the wear and associated air loss leak are likely initially imperceptible but gradually worsen with exposure during which time the audible indication of the air leak becomes more and more obvious.

Since the compressor is continually providing the vehicle air system with pressurized air during its "run" cycle, modest air losses are unlikely to pose a significant degradation in brake performance before detection and replacement of the leaking air systems components.

(4) Chronology -

This investigation has consisted of several joint meetings and field and laboratory inspections. A summary of the major activities is listed below in Table 1.

ODI participated in a series of 25 conference calls conducted among the various manufacturers between July 6, 2009, (initial investigation coordination / planning meeting held in Troy, MI) and October, 2010 (ODI closing of EA09-010). These conference calls addressed numerous technically complex issues by means of investigation assignments, some of which were by supported by manufacturers such as Parker Hannifin (brake line tubing) who provided voluntary assistance though their products were not the primary focus of investigation inquiries. This series of investigation conference calls resulted in 42 completed tasks / sub-tasks.

Approximately 13 tasks / sub-tasks are suspended, remain in-process, or are being monitored.

Table 1 – Summary of Principle Investigation Activity Milestones

Date	Location	Event
June 18, 2009	---	EA09-010 opened – preceded by PE09-012 and PE08-058.
July 6, 2009	Troy, Michigan	Reviewed field performance status; orientation to inspection lab capabilities and evaluation procedures; planned field inspection program e.g. site selections, methods [inspections and component removal was conducted in August followed by the inspection and analysis of the returned parts by each of their respective suppliers.
October 27-28, 2009	Visit Transit Fleet Operation	Inspect and remove pertinent components from selected air brake systems in candidate vehicles. Removed oil samples and components were returned to their respective suppliers for analysis and findings report.

(5) Manufacturers' Actions –

Prior Safety Recall

Prior to the initiation of this investigation (June 18, 2009), New Flyer conducted safety recall 06V-015 in January, 2006 to address the air brake relay valve assembly with a specific date code [342A4K] due to the potential for the [air brake control] valves to have been contaminated … " This recall addressed approximately 103 model year 2004-2005 New Flyer vehicles. At the last required quarterly report provided on June, 2006, New Flyer reported a 100% completion rate (22 inspected and remedied; 81 inspected and did not require remedy).

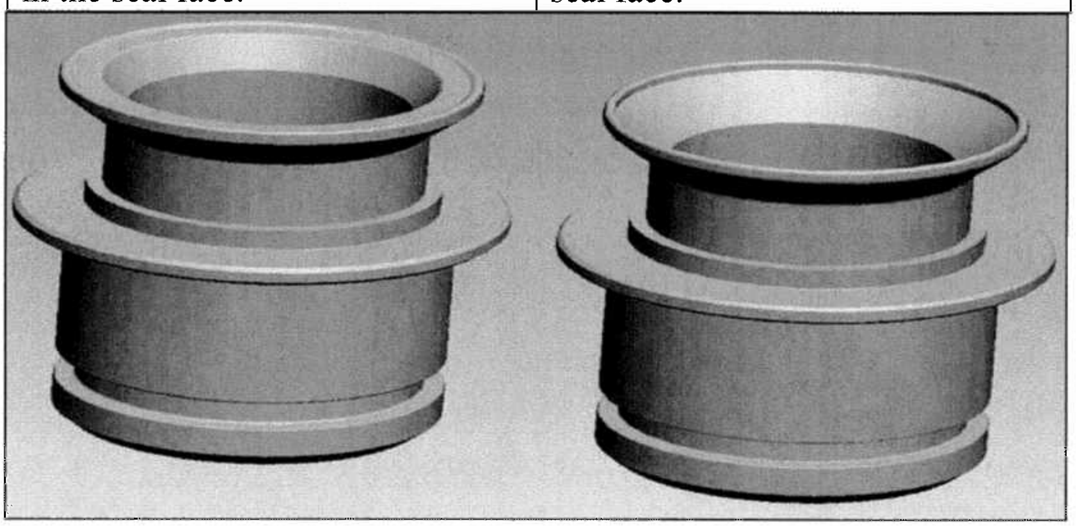
Introduction -

In addition to leading the joint investigation activities, during the course of this investigation the affected manufacturers have taken various actions to improve the operating environment and/or the robustness of the control valve. Following is a summary of the significant actions these manufacturers have taken.

<u>Design Change – Control Valve Modulator Tube</u>

In January 2009, Haldex / Meritor WABCO changed the profile of the circumferential lip of the exhaust seal seat face of the modulator tube. This change reduces the risk of the modulator valve seat deforming and/or cutting the surface of exhaust seal face (when actuated) by distributing the actuation forces over a larger contact area.

Current Design (since January, 2009)	Former Design (prior to January, 2009)
The current modulator tube is designed with a wide "upper" (as shown in the orientation of the photograph) contact face below to reduce the contact pressures and deflections on the rubber face of the mating exhaust valve seal thereby reducing the risk of premature deformation and/or cuts in the seal face.	The former modulator tube is designed with a narrow "upper" (as shown in the orientation of the photograph) contact face which could impose increased contact pressures and deflections in the rubber face of the mating exhaust valve seal facilitating premature deformation and/or cuts on the seal face.



Source: Meritor WABCO Review at ODI December 17, 2009.

Introduction and Availability of Coalescent Air Dryer Filter Cartridges

"Standard" vehicle air dryers are equipped with cartridges that are partially filled with desiccant beads intended to filter and dry the compressed air that passes through the air dryer filter. Coalescent air filters provide an additional (improved) filtration element intended to collect "aerosols" suspended in the compressed system air. "Aerosols" are small airborne oil droplets which are created when small quantities of engine or air compressor lubricating oil pass through the air compressor and are atomized into the vehicle compressed air system flow. "Aerosols" that are not filtered (removed) from the vehicle system air can be deposited on downstream air system components and adversely affect the durability and/or the performance of these components.

New Flyer has advised ODI that "New Flyer introduced coalescing filters in air systems as standard equipment for all buses built with 2010 diesel engines and on all buses equipped with CNG engines built this year [2010]. Some of the grandfathered contracts with 2007 diesel engines were still being built up until the June – July time frame of 2010 [and] these did not have the coalescing filter unless it was already specified in the contract. All future production will be built with coalescing filters."

Alternative Seal Materials Evaluation

Haldex / Meritor have manufactured a limited quantity of (prototype) valves that incorporate exhaust and inlet seals made of materials more resistant to degradation when exposed to BBSA than the currently-specified seal materials. Since there may be trade-offs with other aspects of the materials performance, these companies are selectively deploying these prototypes incorporating the alternative (improved) seal materials into vehicles for evaluation in actual vehicle environments.

(6) Investigation Activities and Findings -

Safety Assessment Statistics -

ODI's had requested that New Flyer provide a summary of warranty and complaint during the predecessor investigation, PE09-012. At that time, New Flyer identified 50 warranty claims that might be pertinent. Warranty claims typically lack specificity and DI's review of the claim information could not determine whether or not these claims indicated any sort of prospective safety concern.

Since that time, New Flyer has indicated that there have been no new reported claims or complaints, as stated in New Flyer's Summary Report (Appendix A) "New Flyer has had no additional reported occurrences of related valve malfunctions since the initial reports in the summer of 2006."

Site Visit -

ODI—in conjunction with representatives from New Flyer, Meritor WABCO and Haldex—conducted a site visit to inspect complaint vehicles. Since no new reports had been received, this work team visited that site of the original 2006 complaints to determine the condition of any unrepaired vehicle found.

During this initial site visit, this work team performed a comprehensive inspection of the vehicle brake systems including brake timing and adjustment, inspected vehicles' service records, and removed the control valve assembly, as well as samples of engine oil and samples of oil contamination found deposited in various parts of the air system, for later laboratory tests. (New Flyer also later collected component and contamination samples from other user sites.)

From the information obtained during the site visit and reported by New Flyer (Appendices A-C), ODI has reached the interim conclusion that contamination was evident in the air system--including contamination of the control valves--and that internal seals of the control valve had been softened. However, the valve function, including actuation timing, appeared to be within the expected range for used, similarly aged valves.

Vehicle Brake System Air Leaks -

Vehicle brake system air leaks typically become an issue when (1) there is a significant rate of air loss (a greater rate of air loss than the on-board air compressor can replenish) [(*)]; and/or (2) there is no apparent audible indication that would prompt a driver or mechanic to investigate, identify and correct the leak.

[(*)] Section 5.1.5 of FMVSS No. 121; Air brake systems requires all air braked vehicle sold in the United States to be equipped with a low pressure warning system intended to alert the operator is the air pressure in the service reservoir is less than 60 psi. (49 CFR § 121 S5.1.5.) In ODI's experience, even at this low pressure condition, the vehicle (if fully charged prior to the leak) should retain sufficient compressed air in the brake reservoir(s) to provide an adequate volume of pressurized air to make several vehicle stops without a need for air replenishment. [(ODI Note: The exact number of the "emergency" stop capability varies depending on several factors, including among others, vehicle brake system and adjustment, vehicle condition and loading, operating grade, pedal stroke application and duration.]

Comparison to Federal Safety Standard Requirements –

Meritor WABCO labs inspected and tested all of the valves returned from field service during and pursuant to this investigation; all valves were found to conform to the brake actuation timing requirement of FMVSS No. 121); Air brake systems. (49 CFR § 121 S.5.3.3.1(a).) Each valve exhibited an actuation time within the range of approximately 0.24 - to 0.36 seconds (refer to pages 3 and 4, Appendix B) —less than the maximum allowable actuation time of 0.45 seconds permitted under the standard.

In short, the suspect field units tested in the "used" condition under laboratory condition conformed to the minimum timing requirements applicable to new vehicle brake systems as required by federal motor vehicle safety standards.

(7) ODI Findings and Assessments -

ODI is closing this investigation for the following reasons

(1) There have been no reported complaints since this investigation was initiated nor, as indicated by New Flyer, since 2006.

(2) This investigation has substantiated the opinion expressed by Meritor WABCO and Haldex in the pre- and early stages of this investigation that BBSA may be found on downstream brake components and that the nylon brake tubing material is most likely source of this contaminant. Parker Hannifin, the manufacturer of the nylon brake tubing for New Flyer vehicles, has confirmed that nylon tubing will "shed" BBSA and that exposure (time) and temperature accelerate the rate at which this material is lost from the brake tubing. The loss of BBSA will cause the tubing to become less flexible, but this is of little concern since there is no need for the tube to be pliant once the tubing has been installed in a fixed location on the vehicle. Since nylon tubing has been installed as brake tubing for many years (estimated at 30 years) without significant changes to the material, the presence of BBSA has likely been a factor in the air brake system environment for a significant period of time. Whether the effects of BBSA were not previously known, whether valves were replaced due to other interceding failure mechanisms, or whether the application, use and/or operating environment has changed remain unanswered questions.

(3) The air control valves and air system valves in general are subject to wear and require eventual replacement. It appears from the reported complaints, that the presence of BBSA has effected a marginal reduction in the affected valve's normal wear-out life expectancy.

An audible air leak was detected in one of the vehicle inspected at the October 2009 site visit. It is not clear whether or not the deteriorating vale seals detected in events leading to New Flyer Campaign 06V-015 exhibited a similar warning. ODI is concerned about the possibility that malfunctioning valves may manifest themselves in diminished braking performance rather than being alerted by an evident, audible air leak which would indicate a need to service the vehicle air system. This possibility --- though not substantiated by the facts developed in EA09-010 --- suggests that a deteriorating air control valve may not be detected promptly in all cases.

Less-than-ideal attention to air system maintenance, though not observed at the October 2009 site visit, could be a further contributing factor to reduced service life and add complexity in the investigation issues where it is observed.

Whether the use of a desiccant filter or a coalescing filter air dryer is, or will be, effective at reducing BBSA is not clear.

(4) "Degraded" valves that were tested conform to Federal Safety Standards applicable to air actuated brake systems installed in new vehicles.

(5) To date, there is scant data indicating that there is an unreasonable risk to motor vehicle safety. There have been no reported crashes, fatalities, injuries, or "close-call" incidents associated with the air control valve in the New Flyer vehicles.

(6) Recent investigation progress has slowed. The investigation issues appear to be more related to a long-term assessment and response to evolutionary changes in the product environment rather than indicative of an overt product defect.

(8) ODI Recommendations -

Given the forgoing assessment, ODI recommends closing this investigation.

G T Bowman | 11/19/10
G. T. Bowman, Safety Defects Engineer | Date

I Concur: R Boyd | 11-19-10
Chief, Medium & Heavy Duty Truck Division | Date

Richard Boyd | 11/19/10
Director, Office of Defect Investigation | Date

EA09-010
October 27-29, 2009

ODI (Bowman) Notes -

Overview: Representatives from New Flyer, Meritor WABCO, and ODI-NHTSA visited xxx to measure vehicle brake performance before and after removing / replacing selected brake system components. Parker Hannifin joined the group at midday on October 28 (second day) to orient themselves to the project (New Flyer had requested Parker Hannifin to assist with brake hose examinations).

New Flyer selected the xxx location because this property is diligent about vehicle maintenance and record-keeping; has demonstrated a willingness to cooperate; and had – in the past, but not recently --- experienced some malfunctioning control valves early in the investigation.

Two vehicles were evaluated:

(1) Unit 501, VIN XXX, Mileage 167, 699
(2) Unit 512, VIN XXX Mileage 167, 566 (hub) / 167,914 (cab) Build date May, 2005. In Service date Sept 6, 2005.

New Flyer selected Unit 501 because this vehicle was equipped with the originally-installed rear brake control valve (i.e. approximately 4 years of service) but was part of a group of vehicle that had previously experienced rear brake control valve malfunctions.

New Flyer selected Unit 512 to determine the condition of the installed relay valve (this vehicle had the rear brake control valve replaced in April 2009) and the condition of selected complementary brake system components (ping tank, oil separator, air dyer, brake line tubing).

Vehicle 501 was road tested in the as-received condition and exhibited stops (adjusted / corrected to 20 mph) of 20.3', 20.0', 22', 20.6, and 21.1 feet) as measured with an in-cab mounted Vericom VC2000 decelerometer. [ODI note: equivalent to 0.58 – 0.63 g deceleration.]

[ODI note: All of the trial sops satisfy the XXX pass-fail criteria of less than 22.5'. According to fleet practice, if stopping distance is between 22.5'and 25', service at next maintenance interval. If the stopping distance is greater than 25', service immediately.]

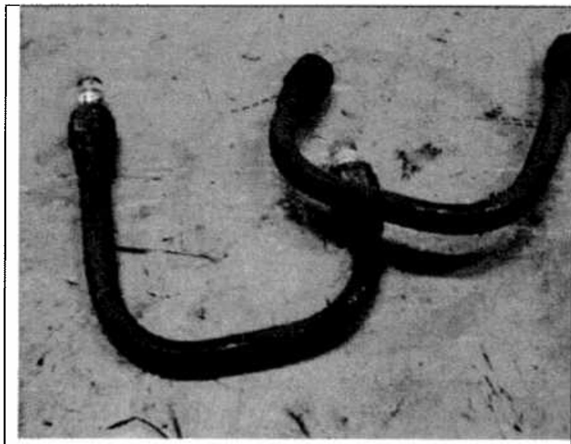
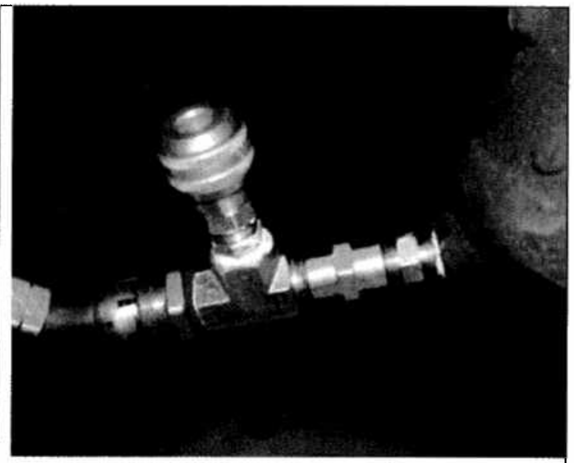
Wet weather prevented taking stopping distance measurements of the post-repair 501 vehicle and both pre and post repair stopping distances for Unit 512.

The selected components (identified above) were removed intact and were not disassembled at XXX. These removed components will be returned to New Flyer and then to their respective suppliers for analysis.

Replacement air control valves were manufactured with a new outlet seal material. An additional 8 of theses "special" (called "Consep") replacement control valves were left with XXX who will replace them in the near future on designated busses at which time the air dryer desiccant filter and samples of the contamination from the primary tank, wet tank, and engine crankcase oil will also be extracted and sent to New Flyer for analysis.

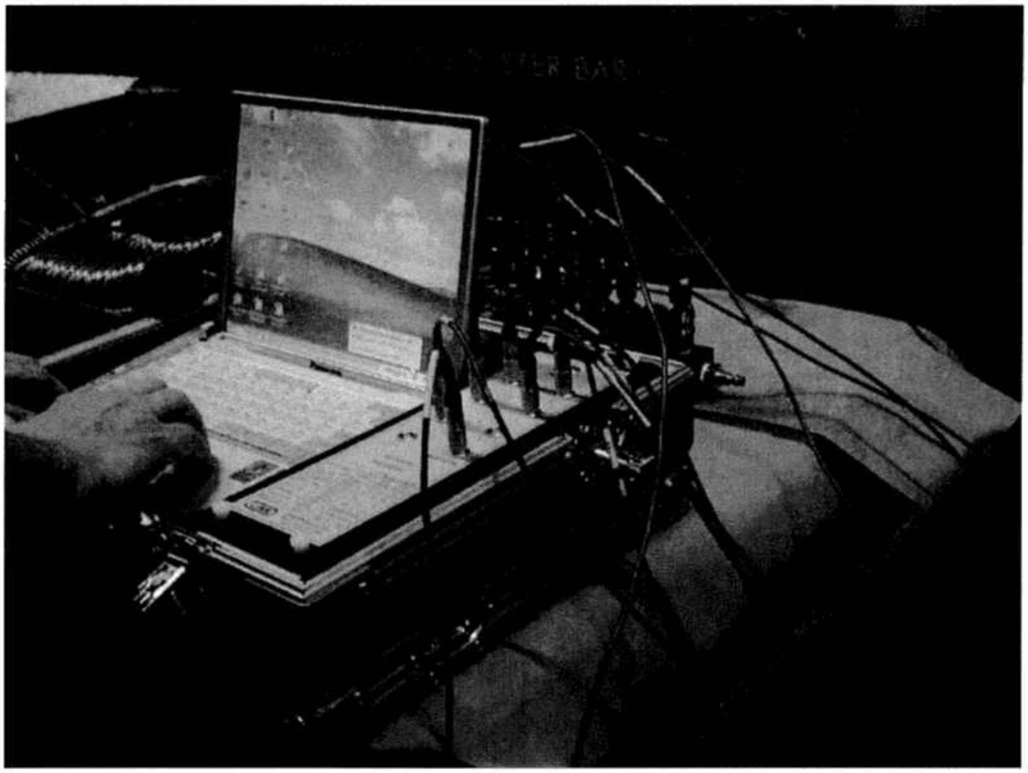
Technicians measured system timing, slack adjuster stroke, and apply and release pressures. An air leak was detected at the rear of Unit 501 though this leak was not of sufficient magnitude to significantly affect stopping distance performance (see notes above).

Measuring the system timing requires installing a "tee" that hosts a transducer installed at the airline at each wheel.

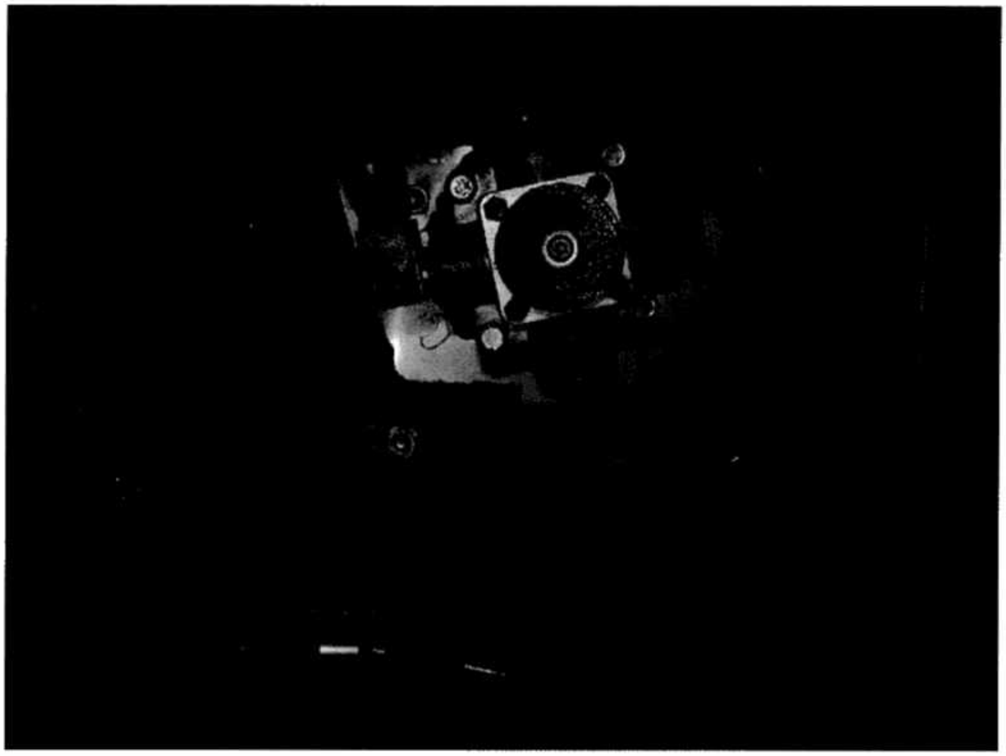
	
Front U-shaped Elbow. "Tee" fitting is installed in the bottommost portion of the "u-shaped" tubing	Rear "tee" installed between the control valve and the rear air chamber

The pressure is measured simultaneously at the treadle and each front and rear brake chamber. Nothing exceptional was noted: the pressure traces tracked each other closely through a series of 30 and 75 second duration zero-to 100 psi apply-and-release cycles.

Note: the installation of transducers is labor intensive and time consuming. Transducers were installed and measurements taken before and after selected brake system components removed for off-site evaluation. Oil samples were extracted from the engine sump, air dyer, and reservoir tanks before any components were removed.

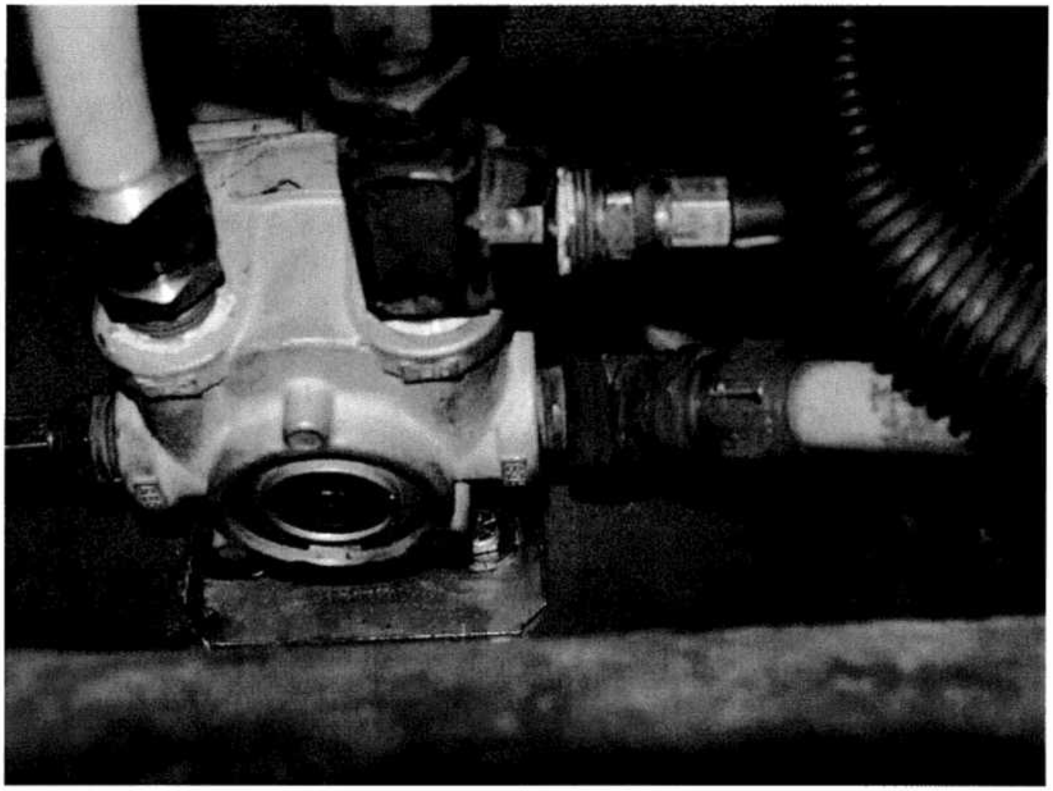


Instrumentation used to measure Brake System Timing

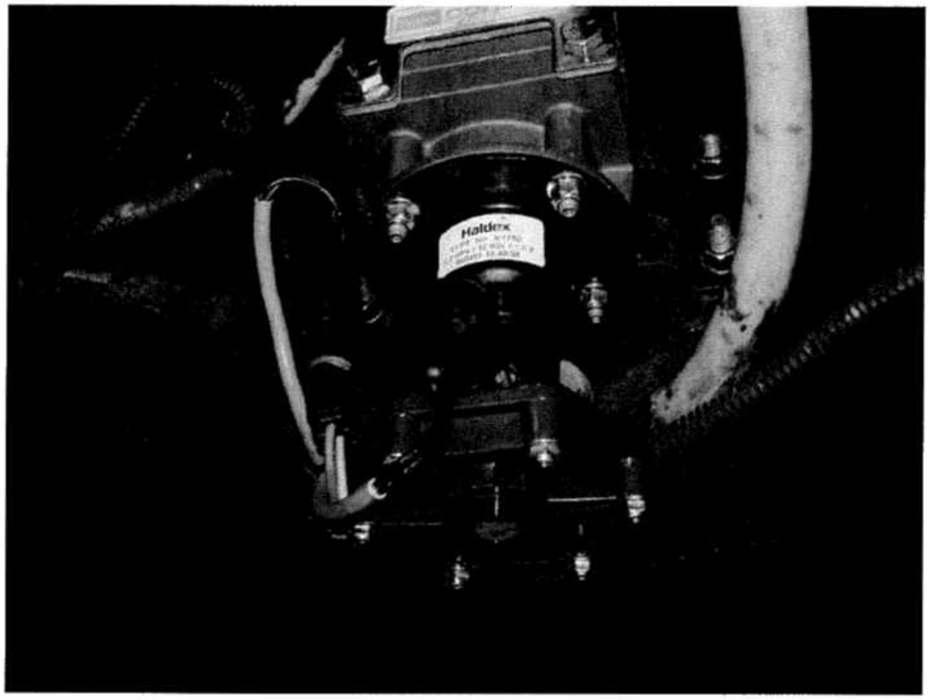


Unit 512, Oil is evident at and around the exhaust port as seen in this bottom view (looking upward at bottom-mounted exhaust seal) of the Bendix treadle valve.

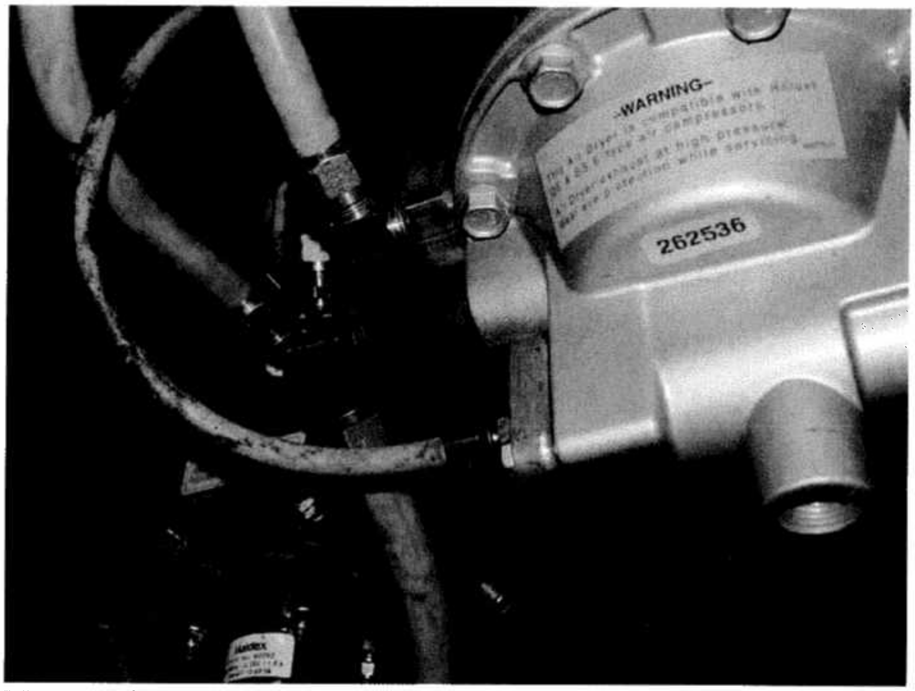
Oil separator, Unit 512 – Component installed ahead of air dryer intended to remove oil centrifugally from brake system air. Red button is the exhaust port; exhibited oil-water discharge. Unit was removed for inspection.



New replacement rear brake control valve as installed.



New replacement oil separator as installed



New replacement air dryer as installed.

NEW FLYER

21 October 2010 VIA EMAIL and MAIL

Tom Bowman
National Highway Traffic Safety Administration (NHTSA)
Office of Defects Investigation
1200 New Jersey Ave. SE,
Washington, DC 20590

Subject: **EA09-010 Meritor WABCO Relay Valve (PN 973 298 070 0) Analysis Report**

Dear Mr. Bowman:

Attached is the Meritor WABCO report on the results of the EA09-010 Working Group valve testing which was conducted on air system brake valves and related components removed from in-service vehicles. These parts for analysis were acquired from a transit agency in the northeast United States last year. References to the transit agency's name have been removed from the report.

The report indicates that even though there were some signs of seal softening, damage, and residues found in the valves, valve function was not compromised beyond normal limitations. New Flyer supports the conclusions of the working group and submits the report for your review.

The subject air brake valve was introduced into New Flyer Production in June of 2004, and is currently installed on over 8800 vehicles North America wide. New Flyer has had no additional reported occurrences of related valve malfunction since the initial report in the summer of 2006.

Considering this, the initial report in 2006 may have been a one-of-a-kind failure, or a misdiagnosis of the failure mode. It is unfortunate that the original two valves associated with those incidents were misplaced and never properly analyzed.

Please contact me if you require clarification of the report contents.

Sincerely,
NEW FLYER OF AMERICA INC.
NEW FLYER INDUSTRIES CANADA ULC

By: Kerry Legg
Vehicle Safety & Regulatory Compliance Manager
Customer Services Head Office
(204) 934-4876

Attachments: EA09-010 Meritor WABCO Report - 101018

MERITOR WABCO

Meritor WABCO Vehicle Control Systems
2135 West Maple Road
Troy, MI 48084-7121
Telephone 248.435.8001
Facsimile 248.435.8002
meritorwabco.com

SUBJECT: Vehicle Report – NE Transit Bus Fleet Vehicle Sampling Activity to Investigate Reduced Vehicle Stopping Performance

CONCLUSIONS:

The rear axle relay (13) and foot (1) valves inspected from this fleet were similar in internal rubber seal and contamination conditions found in other investigations. Rubber seal material softening and tearing were found in the relay valves that would result in air leakage and a slower system response time. The conditions found were not significant that it would have resulted in a significant reduction in vehicle stopping performance which has also been confirmed in the previous evaluations. The 20 MPH stopping distance results on Unit 501 confirmed expected in service performance in the 20.0 to 22.0 foot stop distance. No major vehicle issues were found.

The foot valve leakage and slower release timing found would also contribute to the above reduction in system performance. The foot valve did not exhibit the same rubber seal damages as the relay valve even though the same contamination and chemicals were present in the foot valve.

The SAE J844 (plastic) air brake tubing was found to have as expected reduced levels of plasticizers that confirm the tubing is one of other sources of the BBSA found in the air brake system components.

The vehicle and fleet maintenance records and data were available for this evaluation and the subject air brake systems are getting a satisfactory regime of inspection and maintenance on a regular basis including braking performance testing when the brake system is serviced.

There were no new findings from this inspection and component evaluations that changes the previous conclusions that the rear axle relay valve rubber seals are being softened and damaged due to the contamination present in the air brake system. Further, the air brake tubing in the fleet exhibited the same level of plasticizer loss as the previous plastic tubing from a different supplier indicating the plasticizer environment in the air brake system is a common condition.

BACKGROUND

In Q4 CY 2008, NHTSA ODI initiated activities to investigate reports of reduced vehicle stopping performance related to certain air brake control valves that control the

MERITOR WABCO

Meritor WABCO Vehicle Control Systems
2135 West Maple Road
Troy, MI 48084-7121
Telephone 248.435.8001
Facsimile 248.435.8002
meritorwabco.com

application and release of vehicle rear axle brakes. New Flyer Industries, Meritor WABCO, Haldex Brake Products and Parker Hannifin ParFlex Division have been working with NHTSA to better define the contributing factors and root cause of the reported performance changes on New Flyer Industries vehicles.

In July, 2009, New Flyer Industries, Meritor WABCO, Haldex Brake Products, and NHTSA ODI representatives met to review test results from earlier vehicle samples and to plan further activities to investigate other vehicles that may have signs of brake system performance issues. A transit fleet in the Northeast was selected to conduct an on-site vehicle test and inspection to obtain additional data and product samples for laboratory testing. This fleet was selected based on earlier reports made to New Flyer Industries and product samples provided to Meritor WABCO and Haldex for evaluations.

Representatives from New Flyer Industries, Haldex Brake Products, Parker Hannifin ParFlex Division and Meritor WABCO visited the NE fleet (the "NE fleet" term is being used to identify the fleet customer name for reporting purposes) from October 27, 2009 through October 29, 2009. The goals of the visit were to perform stopping distance tests and collect brake system components and fluid samples from two vehicles. In addition to the data gathering activities ten (10) validation samples of a new Haldex / Meritor WABCO relay valve with improved rubber seals were to be installed on vehicles in the fleet. These valves will be monitored for performance and durability purposes with the fleet.

New Flyer Industries provided representative FMVSS121 brake application (0-60 psi) and brake release (95-5 psi) timing data for the vehicle configuration involved in the investigation:

	Application Time – sec 0-60 psi	Release Time – sec 95-5 psi
FMVSS121 Requirement	0.45 max.	0.55 max.
NFI New Vehicle Data	0.26 (ave.)	0.47 (ave.)

Two buses were provided for the testing and component sampling purposes:

- Unit Number 501: VIN 5FYD4FV165C028224, 162,700 miles
- Unit Number 512: VIN 5FYD4FV105C028235, 167,914 miles

Meritor WABCO Vehicle Control Systems
2135 West Maple Road
Troy, MI 48084-7121
Telephone 248.435.8001
Facsimile 248.435.8002
meritorwabco.com

VEHICLE RESULTS

Vehicle Testing and Inspection

Unit 501 was tested for 20 mph corrected stopping distance using a Varicom instrumentation package provided by New Flyer Industries. Tests were conducted with the vehicle as received and after the rear axle relay valve and other components were replaced. Testing also included brake system FMVSS121 apply and release timing, brake stroke at 90-100 psi and brake threshold pressure measurements. Unit 512, as received, testing did not include the 20 MPH stopping distance but did include the above timing, brake stroke and threshold pressure testing. No repeat testing was done on Unit 512 since the rear axle relay valve was not replaced.

Unit 501

FMVSS121 apply (0-60 psi) and release (95-5 psi) timing:

	As Received		After Replacements	
	Steer Axle	Rear Axle	Steer Axle	Rear Axle
0-60 psi Apply	.31 sec	.355 sec	.32 sec	.275 sec
95-5 psi Release	.365 sec	.515 sec	.38 sec	.53 sec

Brake Strokes at 90-100 psi application:

1.00 in.	1.25 in.	Not re-tested	

Brake Threshold Pressure:

8.1 psi	4.5 psi	Not re-tested	

20 MPH stopping distance (corrected values for speed):

20.3 – 22.0 ft.	20.0 – 22.0 ft.

The following was observed during the vehicle and brake system performance results:

- 20 MPH stopping distance reduced by 10% (approximately 2.0 ft. which is within the 20-22 foot expected range and accuracy of the equipment)
- Rear axle brake application time (0-60 psi) reduced by 22.5% (approximately 0.080 sec.)
- Rear axle brake release time (95 – 5 psi) increased by 3.4% (approximately 0.018 sec).
- Audible air leakage was noted coming from the rear axle relay valve exhaust port with no service brake application. This level of leakage was confirmed with the laboratory testing below.

Unit 512

FMVSS121 apply (0-60 psi) and release (95-5 psi) timing:

	As Received		After Replacements	
	Steer Axle	Rear Axle	Steer Axle	Rear Axle
0-60 psi Apply	.24 sec	.27 sec	Valve not replaced	
95-5 psi Release	38 sec	.555 sec	Valve not replaced	

Brake Strokes at 90-100 psi application:

1.00 in.	1.50 in.		Not re-tested

Brake Threshold Pressure:

7.5 psi	3.9 psi		Not re-tested

20 MPH stopping distance (corrected values for speed):

Not tested	Not tested

The following was observed during the vehicle and brake system performance results:

- The brake system performance, Brake chamber stroke and threshold pressure data was as expected.
- Nothing was found to be out of the ordinary during the above testing.

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Meritor WABCO Vehicle Control Systems
2135 West Maple Road
Troy, MI 48084-7121
Telephone 248.435.8001
Facsimile 248.435.8002
meritorwabco.com

The rear axle brake relay valve on this vehicle was removed from the vehicle in an earlier field sampling activity in June 2009 (results included in this report for reference)

Brake system component samples, engine crankcase oil samples and liquid sample swabs of various air brake system areas were taken from both vehicles. All samples were returned to Haldex, Parker Hannifin or Meritor WABCO for engineering evaluations. The following is the samples taken from each vehicle.

Unit 501

- Components: Rear axle relay valve, air dryer, oil separator, muffler (ping) reservoir
- Plastic tubing samples from: Inlet to oil separator, oil separator to air dryer, relay valve to ABS modulator valve
- Air reservoir samples – supply, primary, secondary, accessory, emergency release, muffler (ping)
- Swabs – foot valve exhaust cavity, air dryer purge port (A/D end)

Unit 512

- Components: air dryer, foot valve
- Plastic tubing samples: Oil separator to air dryer, tubing to the oil separator was sampled prior to the fleet visit)
- Air reservoir Samples – supply, primary, secondary, accessory, emergency release
- Swabs – foot valve exhaust cavity, air dryer purge port (A/D end), oil separator drain valve exhaust cavity

Nine (9) Haldex / Meritor WABCO rear axle relay valves with the Phase I modulating piston change and Phase II improved rubber seal materials were left with the fleet to be installed after the onsite inspection visit and returned to Haldex for analysis. Eight valves were returned for evaluation and the results are included in this report.

Laboratory Testing

Relay Valve (Unit 501)

Standard engineering test procedures were followed to evaluate leakage, input / output performance, and apply / release times. After testing the valve was disassembled and inspected for contamination and seal conditions. The components and any contamination was then subject to a chemical analysis in the materials lab.

MERITOR WABCO

Meritor WABCO Vehicle Control Systems
2135 West Maple Road
Troy, MI 48084-7121
Telephone 248.435.8001
Facsimile 248.435.8002
meritorwabco.com

Overall leakage (both supply and delivery conditions) were greater than a new OEM valve leakage level. The maximum leakage rate found was greater than 5000 standard cubic centimeters per minute (exceeded instrumentation capacity) which was similar to other samples taken previously. Valve initial crack pressure was within new OEM specifications and the input / output performance was within acceptable in service levels. The apply / release times (per the engineering set-up) were greater than a new OEM valve specification and again within the previous results found on similar valves in service.

The inlet rubber seal was found to be swollen, soft, and pitted around the seat witness diameter including a permanent material set (compression). The exhaust rubber seal was found to be slightly softer and had a deep cut where the seal mates with the exhaust seat. These conditions correlate to the change in leakage and general input / output performance levels found.

The chemical analysis also confirmed similar chemicals and contamination found in the earlier samples.

See Attachment “C”, “D”, “E” for additional data.

Foot Valve (Unit 512)

The valve was not a Meritor WABCO or Haldex product but industry standard engineering test procedures were followed to evaluate leakage, input / output performance, and apply / release times. After testing the valve was disassembled and inspected for contamination and seal conditions. The components and any contamination was then subject to a chemical analysis in the materials lab.

Overall leakage was found to be excessive and specifically related to the primary (top) circuit. This was found to be caused by a cut o-ring between the primary body and the plunger upper body. The o-ring condition was not determined to be related to the contamination but due to an assembly error or other related installation issue.

Application timing was found to be within new OEM levels and the release timing to be slower (5%) than a new OEM benchmark performance. The impact on vehicle performance was determined to not be significant. Overall input / output performance levels compared to new OEM benchmarks was slightly lower and in the area of internal component travels and loads.

Internal contamination was found in the presence of liquid oil residue on both primary and secondary pistons and internal cavities. Both inlet and exhaust rubber seals exhibited some wear and set in the seat contact diameters as expected. No excessive swelling, softening or tears were found in the rubber seals. Seal hardness were found to be slightly softer than a new OEM benchmark and contamination and chemicals found were the

Meritor WABCO Vehicle Control Systems
2135 West Maple Road
Troy, MI 48084-7121
Telephone 248.435.8001
Facsimile 248.435.8002
meritorwabco.com

same as the conditions found in the rear axle relay valve above. See Attachment “C”, “D”, and “E”.

Air Dryer Cartridge and Oil Separator

Rubber seals (3) were found to be within normal service conditions with no major change in hardness or size. All seal extractables were found to be in the low / normal range. The chemical composition of the contamination found was similar to previous samples in other vehicle applications. MS/CG scans confirmed no significant differences as found before.

Engine Oil Analysis

Samples from both vehicles were found to be within normal service ranges. No significant levels of contamination were found Typical MS/CG levels were detected and no GC peaks were found.

Air Brake Tubing

Three (3) plastic tubing (SAE J844) samples were removed from each vehicle from agreed to locations in the air brake system. The purpose was to evaluate the level of plasticizers (BBSA) in these areas that could indicate the source of the plasticizer found in the rear axle relay valve and other devices. Locations were:

1. Between the air compressor and inlet to the oil separator
2. Between the oil separator and the inlet to the air dryer
3. Between the relay valve and ABS modulators.

In addition to these field samples new tubing samples were used in the analysis as a control base line. The field samples were determined to be original OEM installations with one exception that the tubing had been sampled in the earlier initiative.

Testing included standard industry practices to evaluate the level of plasticizer (% extractables) and structural stiffness.

New nylon 11 OEM tubing would have in the range of 11-13% extractables and a stiffness level (force to flex 2 inches around a mandrel) of approximately 50 lbs in the tubing size sampled for this analysis. Tubing taken between the compressor and initial reservoirs were found to have a range of 6.0 – 6.5% extractables and a stiffness of approximately 58 lbs indicating an approximately 40% to 50% loss of plasticizer. The tubing between the relay valve and ABS modulator had an 11% level of extractables and a stiffness of approximately 50 lbs, indicating relatively little plasticizer loss. This result confirms the general industry experience that SAE J844 type tubing does lose plasticizers over time where temperatures are greater than ambient. The reduction in the amount of plasticizers has an inverse relationship with the stiffness feature, i.e. as plasticizer is lost, tubing stiffness increases. The data also follows similar results found in the previous evaluations of another tubing supplier material.

Test results confirmed earlier findings that plasticizer (BBSA) exists in the air brake system and that the SAE J844 tubing is one of other sources. The tubing was also confirmed to be within engineering expectations in service and would not be a risk for proper operation in service. See Attachment "B".

Relay Valve Samples (Units 502, 503, 504, 505, 711, 712, 752, 753)

In addition to the relay valve sampled in the inspection, the fleet in parallel with the visit has followed up and removed an additional eight (8) relay valves. This action was agreed by the investigation parties to put into field testing the new relay valve rubber seal materials for validation in vehicles where the current seals were seeing contamination and damage. The vehicles involved were also part of the two lots of vehicles manufactured by New Flyer Industries and noted in this report.

The eight (8) valves were returned for a similar evaluation and internal inspection. In all valves inlet and exhaust rubber seals were subjected to the contamination. The seal softening and damage conditions were also found to varying degrees.

See Attachment "F" for pictures of the seals.

FLEET GENERAL INFORMATION

Fleet is a local public transit agency that had purchased two (2) production lots (Sales Releases) of the New Flyer Industries model D40LF (Diesel engine, 40 foot, low floor) buses. First vehicle build was for 48 vehicles (SR-1043) in June – September 2005. The second vehicle build was for 43 vehicles (SR-1185) in July – September 2007. The common vehicle and brake system features of interest were:

- Cummins ISL-05 and ISL-07 engines
- WABCO 18.7 CFM air compressor
- Air dryer
- No coalescing filter / dryer cartridge
- Separate oil separator / heat exchanger installed before the air dryer
- Duron E 15w40 Volvoline Premium conventional and synthetic engine oils (CI-4 and CH-4 / 5J) based on vehicle build dates

In June 2009, prior to the subject site visit, four (4) rear axle relay valves were sampled by New Flyer Industries and provided to Meritor WABCO / Haldex for laboratory testing and inspection for internal contamination and rubber seal degradation. Vehicle mileages ranged from 75,429 to 152,339 miles and the valves were determined to be original installed valves in the 2005-2007 timeframes. All valves were tested to the standard Meritor WABCO engineering test procedures. All valves were disassembled and inspected for contamination and rubber seal degradation.

Three (3) relay valves were manufactured by Haldex and one (1) relay valve was manufactured by another OEM valve supplier.

All valves exhibited low to moderate levels (as defined by Meritor WABCO engineering experience) of liquids / oil, contamination deposits (solids) and other particulates. Inlet valve rubber damage (softening and tearing) was found on all three (3) Haldex valves. No seal damage was found on the other OEM valve and all exhaust valve rubber seals.

All valves exhibited the same chemicals in the contamination that have been found in other air brake systems that have shown relay valve rubber seal damage. Two (2) valves from the vehicles with 148,295 – to 152,339 miles exhibited the chemical BBSA (plasticizer) while no BBSA was found in the other two (2) valves that had 75,429 – 75,690 miles.

Actual fleet service data and records were provided for this evaluation. Based on these records, there is consistent and proper maintenance of the fleet vehicles. Records also confirm that a vehicle stopping performance check is made when any service is made to the braking system. Based on the earlier vehicle inspection experience, the air brake system is considered to be typical for a system that is given regular maintenance and inspections. No evidence of insufficient maintenance was found.

See Attachment “A” for a summary of the test and inspection details.

SUMMARY OF FINAL CONCLUSIONS

Air brake system contamination and specifically BBSA were found in relay valves that exhibited rubber seal degradation. Relay valves that were contaminated still performed within acceptable engineering limits considering the age and service mileages found. No significant reduction in overall braking performance was found in the “as is” vehicle condition even though air brake system contamination and rear axle relay valve seal damage was found.

The Haldex / Meritor WABCO relay valve design improvements that have been implemented (Phase I) and that are in process of implementation (Phase II) will improve the valve robustness against the internal air brake system operating environment. Further industry work to understand the other sources of contamination and the actual cause of rubber seal damage is still needed. Vehicles equipped with additional air filtration and especially coalescing filters or air dryers with these coalescing filter features have shown

Meritor WABCO Vehicle Control Systems
2135 West Maple Road
Troy, MI 48084-7121
Telephone 248.435.8001
Facsimile 248.435.8002
meritorwabco.com

to be effective in reducing the levels of contamination in the air brake system and specifically the rear axle relay valves.

ATTACHMENTS:

A. Summary of Four Relay Valves Inspected Prior to the Fleet Visit
B. Stiffness and Percent Extractables Test Summary – Parker Hannifin Corp.
C. Relay Valve and Foot Valve Evaluation Report – Meritor WABCO
D. Materials Lab Analysis of Various Samples From Two Buses – ArvinMeritor
E. Material Lab Analysis of Used Valves – ArvinMeritor
F. Relay Valve (8) Seal Pictures - Haldex

Final report: 10/12/10

PMJ

MERITOR WABCO

Meritor WABCO Vehicle Control Systems
2135 West Maple Road
Troy, MI 48084-7121
Telephone 248.435.8001
Facsimile 248.435.8002
meritorwabco.com

ATTACHMENT A: Summary of Relay Valves Inspected Prior to Fleet Site Visit

Vehicle Information				Valve Sample Information			Leakage (No Del 20sccm Max, Del 30sccm Max)					Timing		Crack	Seal Damage (Y/N)	
												Apply	Release	Pressure		
Tracking #	Vehicle #	In-Service	Mileage	Sample #	Make	Mfr Date	15psi No Del	135psi No Del	15psi Del	60psi Del	135psi Del	(0.125sec Max)	(0.300sec Max)	4.6±1.5psi	IL Seal	Exh Seal
SR-1043	511	6-Sep-05	148,295	NF-27	MW	1-Apr-05	>5 LPM	100	50	550	40	0.122	0.219	4.2	Y	N
SR-1043	512	6-Sep-05	152,339	NF-29	MW	15-Apr-05	>5 LPM	>5 LPM	40	3	140	0.128	0.228	4.7	Y	N
SR-1185	712	19-Jul-07	75,690	NF-28	MW	9-May-07	5	110	60	50	50	0.123	0.216	4.7	Y	N
SR-1185	711	17-Jul-07	75,429	NF-30	OEM	8-Aug-05	0	0	2	2	4	0.106	0.245	4.7	—	N