



Oronite

FR-861
Amtrak General Electric
Transportation
Evaluation of a B-20 Biodiesel in a
General Electric P-32 Locomotive

March 2010 – June 2011

Chevron Oronite Company LLC
Industrial Engine Oils
Richmond, California

Prepared by
P. Van Slyke
D. Anderson

Contents

Summary	1
Fuel and Oil	1
Piston Deposit Ratings	2
Engine Sludge	2
Liner Wear	3
Additional Inspections – Cylinders 5R and 5L	4
Piston Rings	4
Connecting Rod Bearings	4
Oil Performance	6
Conclusion	8

Appendices

1 Fuel Inspection	9
2 Piston and Sludge Deposits Worksheet	10
3 Liner, Piston Ring, and Bearing Wear Worksheet	11
4 Used Oil Data and Charts	12
5 Photographs	13

© 2011 by Chevron Oronite Companies LLC.

This document contains Chevron’s confidential and proprietary information. Use of this document is prohibited, except as authorized by Chevron Oronite Companies LLC and/or its affiliated Chevron companies.

ENGINE INSPECTION OF AMTRAK UNIT #500

Summary

After completing one year of operational testing on B20 biodiesel testing, Unit #500 was brought to Amtrak's facility in Chicago for a detailed inspection of two power assemblies. The power assemblies located in positions 2R and 2L had been premeasured prior to testing and installed in Unit #500. On June 7, 2011, the premeasured power assemblies were removed from the engine for inspection to determine wear and engine deposits. The levels of piston deposits, surface sludge, ring and liner wear, and connecting rod bearing condition were inspected and evaluated. Also performed were a video image scope inspection of cylinders 5R and 5L *in situ* and a visual inspection of injector tip deposits of these cylinders. The injectors showed carbonaceous deposits on the tips. It is unknown if the deposits were affecting fuel flow. A video image scope of 5R and 5L liners showed evidence of rusting as a result of past water leaks. In addition to the engine inspection, used oil condition was monitored and analyzed at Oronite's facility in Richmond, California, during the course of the test. Prior to the start of testing a sample of the biofuel (B100) and biodiesel (B20) was analyzed. The B100 was analyzed for glycerin, water, and oxidative stability. Also, biodiesel samples (B20) were analyzed for biodiesel content during the course of the test.

The results of the testing show no abnormal conditions as related to engine deposits or engine wear. The condition of the parts was deemed comparable to normal conditions as experienced on passenger and freight locomotive operations. The engine parts inspected showed normal piston deposits. The liner wear was minimal, with most of the original crosshatch still evident. Piston rings also showed low wear and were in serviceable condition. The engine bearings showed normal wear (overlay not worn through) and even loading with no evidence of corrosion. Used oil and fuel analysis showed the oil to be in good condition over the course of the one year test and biodiesel content was at the B20 level over the one-year test. Though the locomotive experienced some operational issues during the sixteen month test period (Feb 2010 – May 2011), no operational difficulties were experienced due to oil or fuel condition.

This test protocol focused on the operational performance of only one locomotive. Locomotive Maintenance Officers Association (LMOA) established field test guidelines specify the use of a minimum of four test and two reference locomotives to generate multiple data points while effectively addressing operational issues that sometimes occur with individual locomotives during the test period. Definitive conclusions or commentary regarding the consumption of B20 biodiesel in locomotive engines in diverse service applications is not in the scope of this report.

Fuel and Oil

The fuel used during the test was a low sulfur diesel fuel splash blended to B20 with a transesterified tallow based biofuel. A sample of the B100 was sent to the Oronite test lab for analysis. Oronite conducted test methods for glycerin, water, and oxidative stability on the B100 and B20 sample for quality and the results showed the B100 and B20 to be within specifications. Samples of the test fuel (B20) were periodically sent to the Oronite test lab. The data set shows

that the fuel remained at the B20 level over the course of testing. Test results can be found in Appendix 1.

The oil used for the test was a commercially available 20W-40 multigrade Generation 5 locomotive oil. Samples of the used oil were taken monthly and sent to the Oronite lab for analysis. See discussion of the used oil analysis findings below.

Piston Deposit Ratings

Two premeasured power assemblies at cylinder positions of 2L and 2R were removed from the test unit. Parts removed and inspected for deposits were the liner cylinder head assembly and the pistons.

The two pistons were rated using the Coordinating Research Council (CRC) diesel piston rating method. Table 1 summarizes the piston deposits from Amtrak Unit #500. The table below shows that Unit #500 had moderate piston deposits that are consistent with other passenger and freight service. Though the ratings appear to be in alignment with inspection results for locomotives in moderate to severe service (MWH/month), the operational conditions, duty cycle, and MWH usage of Unit #500 was not available at the time of inspection. The detailed rating sheets can be found in Appendix 2-1 and 2-2. Photos can be found in Appendix 5-1 and 5-2.

Table 1

Piston Deposit Ratings CRC Unweighted Demerits

Piston Zone	2R	2L
Groove #1	45.3	47.2
Groove #2	49.1	49.1
Groove Oil	0.0	0.0
Crownland	35.7	29.1
Land #2	14.9	16.3
Land #3	0.0	0.0
Total Demerits	145	142

Engine Sludge

The following areas were rated for sludge:

- Rocker box cover
- Rocker box and valve gear
- Crankcase Cover
- Crankcase “A” frame

The rocker boxes were rated using the CRC Sludge Merit Rating scale. Sludge ratings are made on a merit basis wherein a rating of 10 designates a part completely free of sludge and where parts with increased accumulations of sludge are represented by lower rating numbers. The sludge rating is based on the sludge depth and area covered not the color or character of the deposits.

As Table 3 illustrates, the rocker boxes were free of any significant sludge with very little, if any, depth. The table shows the average ratings of both test cylinders. Detailed ratings can be found in Appendix 2-3. Photos can be found in Appendix 5-3, 5-4, and 5-5.

Table 3
CRC Sludge Deposit Ratings

Piston Zone	2R	2L
Crankcase Cover	9.75	9.75
Rocker Cover	9.56	9.56
Crankcase A Frame	9.50	9.50
Rocker Box	9.63	9.63

Liner Wear

Liner 2R and 2L were visually inspected. They were evaluated at the top and bottom of the piston stroke and on the thrust and anti-thrust sides. The liners were observed for any wear anomalies including scuffing, polishing, and scratching. The liners showed very little wear. No liner showed evidence of scuffing. There was some incipient bore polishing occurring at the top ring reversal area, however, the area of polishing was mild. Overall, the liners were in good, serviceable condition. Detailed ratings can be found in Appendix 3-1. Photos can be found in Appendix 5-6.

A surface finish study was conducted on the liner using a Mahr Surf surface finish measuring device. Surface measurements were taken at the bottom of the liner in the “no wear” area below piston travel, in the middle of the liner and at the top of the liner. At the top of the liner the surface finish measurements were taken with the lacquer/varnish material, and with the lacquer/varnish material removed with vinegar (acetic acid). The table below shows the results of the measurements of the average peak to valley (Rz) in microinches at a 0.07-inch traversing length.

Amtrak Unit 500
Average Peak to Valley (Rz), Microinches

Piston Zone	2L	2R
Top With Lacquer	118	84.5
Top Without Lacquer	103	138
Middle	135	97.5
No Wear Bottom	160	117

Additional Inspections – Cylinders 5R and 5L

The fuel injectors were removed from cylinders 5R and 5L and a boroscope inspection was performed on the liners through the injector hole. There was evidence of staining, either from rust or corrosion on the liner surfaces. Discussions with the shop foreman determined that the locomotive had experienced a storage-related failure in the past and was most likely the cause of the abnormal appearance of the liners. Engine operation and used oil analysis indicated that there are no operational difficulties as a result. Inspection of the injectors showed that there was a moderate level of carbonaceous deposits on the injector tips. With 5X magnification it appeared that the injector tip spray nozzles were not occluded, however it was indeterminate if there was any loss in injector performance or interruption of the spray pattern as a result of the deposits. Photos of the injector tips are in Appendix 5-7.

Piston Rings

The piston rings were removed from the pistons of both power assemblies removed from Unit #500 and brought back to Oronite’s Richmond facility for inspection. The piston rings were inspected visually for evidence of abnormal wear and deposits and measured in comparison to the pre-test measurements. The ring faces were examined under magnification and showed only signs of normal wear. There was no evidence of scoring or scuffing. Visual evaluation of the carbon deposits were also made on the piston rings. The carbon buildup corresponded to that of the pistons and was in the medium to light range based on the CRC rating system. The measurement data, visual inspection, and deposit ratings showed the rings to be in normal, serviceable condition. Detailed measurements of the piston rings are in Appendix 3-2 and 3-3. Photos can be found in Appendix 5-8

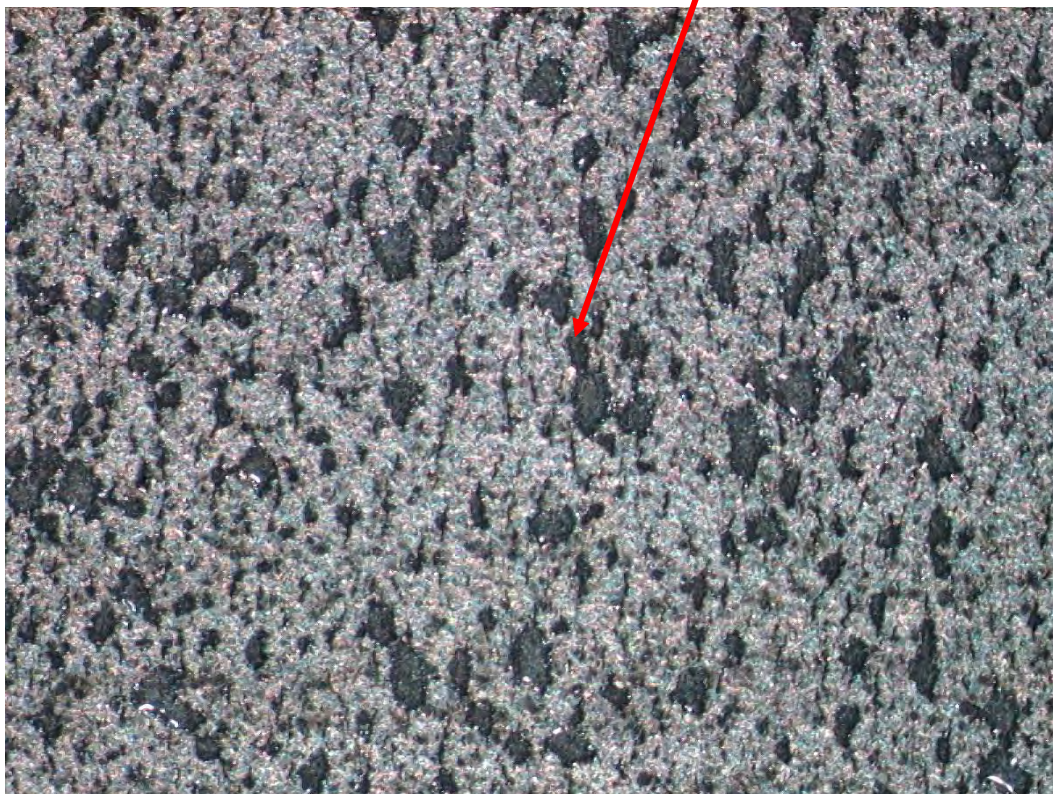
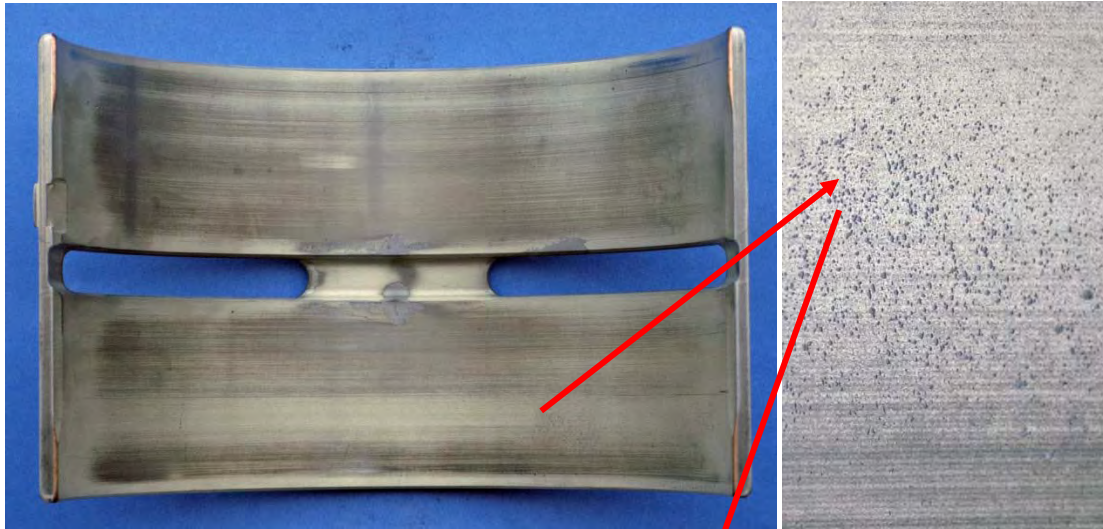
Connecting Rod Bearings

The connecting rod bearings from Unit #500 were visually inspected for wear. The bearings showed normal wear patterns and even loading and were in serviceable condition. Closer inspection under magnification showed signs of pitting and metal migration on only the bottom shells of the bearings. Biodiesel has been documented to cause bearing corrosion when there is dilution in the oil sump. There is concern that the pitting may be caused by this corrosive mechanism. The bearings were brought back to Oronite and were analyzed at Oronite’s Tribology lab. After visual inspection bearings were sent to GE for more detailed examination

Confidential
Copyright © 2011 by
Chevron Oronite Companies LLC.
To be reproduced and used only in accordance with
written permission of Chevron Oronite Companies LLC.

of the pitting to determine cause. Ratings of the bearing can be found in Appendix 3-4. Photos can be found in Appendix 5-9.

The area of pitting was covered with small cracks and pits and the pits appear to be aligned with the cracks. The cracks appear to be enlarging into pits via fracture of the edge. The examined pits appear to be caused by mechanical rather than chemical action or corrosion. Further investigation is needed as to the cause of the initial cracking. The photographs below show a magnified image of the cracking and pitting of the bearing flashing and overlay surface. See figures below.



Confidential
Copyright © 2011 by
Chevron Oronite Companies LLC.
To be reproduced and used only in accordance with
written permission of Chevron Oronite Companies LLC.

Oil Performance

Appendices 4-1 through 4-8 are plots of the used oil analysis showing the oils performance during the test. The used oil samples were collected by Amtrak personnel and were received by Oronite. Analyses were performed by Chevron's Analytical labs. The oil was analyzed for:

- Viscosity increase by ASTM D445
- Base Number (BN) by ASTM D4739 and Acid Number (AN) by ASTM D664
- Pentane insolubles by the LMOA method by ASTM D7317
- Oxidation by IR
- Wear metals by ASTM D5185
- Fuel dilution by ASTM D3524 and biodiesel dilution by Oronite proprietary methods

These data show all parameters to be within condemning limits. A complete summary of the oil analysis data can be found in Appendix 4-1.

Note: The trend data implies that the oil was changed at approximately 60 days, 270 days, and 400 days, however Oronite does not have maintenance records to verify.

The plots of the 100°C viscosity (Appendix 4-2) showed no significant increase in viscosity up to when the oil was changed.

Appendix 4-3 plots the AN and BN. The BN retention was good, dropping to a low of 7.37 mm KOH/g. The AN rose slightly over this same time period to 4.18 mm KOH/g before dropping.

Coagulated pentane insolubles by the LMOA method are plotted in Appendix 4-4. They remained low with a maximum of 2.6 wt %.

Oxidation of the engine oil was measured by DIR method. The graph in Appendix 4-5 show that oxidation was under control and remained low for the entire duration of the test.

Wear metals (iron, copper, and lead) were measured using the ICP method. For all three, the levels were very low and well within the condemning limits. Appendices 4-6 through 4-8 show the wear metal trends.

Fuel dilution (total) and biodiesel dilution were also monitored. As an acidic material, biodiesel dilution in the oil may be problematic being corrosive to metallic surfaces. For the duration of the test both total fuel dilution and biodiesel dilution were very low and in many observations were below measurement limit. The table below shows the results of the dilutions.

Total and Biodiesel Dilution in Locomotive #500

Date	Fuel Dilution, %	Bio Content, %
03/01/10	0.0	0.0
03/08/10	<1	<0.5
03/18/10	<1	<0.5
04/03/10	<1	<0.5
04/06/10	<1	<0.5
04/16/10	<1	<0.5
04/26/10	<1	<0.5
05/06/10	<1	<0.5
06/10/10	<1	<0.5
06/20/10	<1	<0.5
06/30/10	<1	<0.5
07/12/10	<1	<0.5
07/20/10	<1	<0.5
08/09/10	<1	<0.5
08/20/10	<1	<0.5
09/13/10	1.2	<0.5
09/23/10	<1.0	<0.5
10/05/10	<1.0	0.7
10/13/10	<1.0	0.6
10/23/10	<1.0	0.6
11/01/10	1.2	0.6
12/08/10	2.5	<0.5
12/10/10	2.5	<0.5
01/27/11	3.0	<0.5
02/22/11	1.2	<0.5
03/02/11	1.1	<0.5
03/09/11	<1.0	0.5
03/22/11	<1.0	0.5
04/15/11	1.3	<0.5
04/26/11	1.9	<0.5
05/05/11	2.0	<0.5
06/06/11	1.7	<0.5

Confidential
 Copyright © 2011 by
 Chevron Oronite Companies LLC.
 To be reproduced and used only in accordance with
 written permission of Chevron Oronite Companies LLC.

Conclusion

Amtrak Unit #500 completed a one-year operational field trial using B20 biodiesel. A field inspection consisting of evaluating the engine for deposits and wear resulted in the following observations. In addition, used oil condition and fuel quality was monitored and analyzed to determine oil performance.

- Inspection of the 2R and 2L power assemblies showed moderate piston deposits and very clean engine surfaces lacking any sludge or deposit depth.
- Inspection of the 2R and 2L power assemblies showed minimal wear to the cylinder liners and piston rings.
- Inspection of the 2R and 2L connecting rod bearings showed normal wear. Evidence of small pitting is not caused by corrosion and needs to be investigated further.
- Used oil analysis exhibited good viscosity control.
- Used oil analysis exhibited good base retention and acid control.
- Used oil analysis exhibited good insoluble control.
- Used oil analysis exhibited good oxidation control.
- Used oil analysis exhibited very low wear metals (Pb, Cu, Fe) indicating low wear.

Appendix 1
Fuel Inspection

B100 Analysis

Test	Specification	Result
Free Glycerin	0.020% Max.	0.011%
Total Glycerin	0.240% Max.	0.118%
Oxidation Stability	3 Hrs Min.	41.8 Hrs
Karl Fisher Water ¹	400 ppm Max.	106 ppm

¹ In lieu of ASTM D2709 Water and Sediment

Biodiesel Concentration in Amtrak Samples

Date of Sample Sent to Oronite	Biodiesel Content, %
12/23/2009	22.4
2/9/2010	22.2
2/11/2010	20.1
4/3/2010	22.4
7/7/2010	23.4
7/27/2010	22.2
8/9/2010	21.8
9/13/2010	20.6
10/23/2010	23.0
1/27/2011	22.0
2/22/2010	20.0
3/27/2011	20.9
4/26/2011	19.5
5/9/2011	22.0

Appendix 2

Piston and Sludge Deposits Worksheet

- Appendix 2-1: GE Piston Deposit Measurements, Cylinder # 2L
- Appendix 2-2: GE Piston Deposit Measurements, Cylinder # 2R
- Appendix 2-3: GE Sludge Ratings

Appendix 2-1
AMTRAK B-20 TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE
GE Piston Deposit Measurements

Cylinder # 2L
 Top Groove Fill 47.2
 Total Deposits 142

Description of Deposits and Location

Piston Zone	1st. Quadrant										2nd. Quadrant									
	HC	MC	LC	VLC	BL	DBr	AL	LAL	VLA	Clean	HC	MC	LC	VLC	BL	DBr	AL	LAL	VLA	Clean
Grooves #1		95	5								5	50	45							
Grooves #2		95	5									100								
Oil #1										100										100
Crownland		10	20	70								40	15	45						
Land #2			10	85	5								10	80	10					
Land #3										100										100
Land #4										100										100
Zone	3rd. Quadrant										4th. Quadrant									
Grooves #1	HC	MC	LC	VLC	BL	DBr	AL	LAL	VLA	Clean	HC	MC	LC	VLC	BL	DBr	AL	LAL	VLA	Clean
Grooves #1		100										95	5							
Grooves #2		95	5									95	5							
Oil #1										100										100
Crownland		50	45	5								30	30	40						
Land #2			30	70									10	90						
Land #3										100										100
Land #4										100										100

CRC Demerit Rating Summary

Piston Zone	1st Q	2nd Q	3rd Q	4th Q	Avg.
Grooves #1	48.8	41.3	50.0	48.8	47.2
Grooves #2	48.8	50.0	48.8	48.8	49.1
Oil #1	0.0	0.0	0.0	0.0	0.0
Crownland	20.5	30.5	37.0	28.5	29.1
Land #2	15.8	15.5	18.0	16.0	16.3
Land #3	0.0	0.0	0.0	0.0	0.0
Land #4	0.0	0.0	0.0	0.0	0.0

RATING SCALE

- HC - Heavy Carbon
- MC - Medium Carbon
- LC - Light Carbon
- VLC - Very Light Carbon
- BL - Black Lacquer
- DBr - Dark Brown Lacquer
- AL - Amber Lacquer
- LAL - Light Amber Lacquer
- VLA - Very Light Amber Lacquer

Appendix 2-2
AMTRAK B-20 TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE
GE Piston Deposit Measurements

Cylinder # 2R
Top Groove Fill 45.3
Total Deposits 145

Description of Deposits and Location

Piston Zone	1st. Quadrant										2nd. Quadrant									
	HC	MC	LC	VLC	BL	DBr	AL	LAL	VLA	Clean	HC	MC	LC	VLC	BL	DBr	AL	LAL	VLA	Clean
Grooves #1		25	75								5	90	5							
Grooves #2		100										90		10						
Oil #1										100										100
Crownland		55	30	15							5	30	30	35						
Land #2			10	80	10									90	10					
Land #3										100										100
Land #4										100										100
Zone	3rd. Quadrant										4th. Quadrant									
Grooves #1	HC	MC	LC	VLC	BL	DBr	AL	LAL	VLA	Clean	HC	MC	LC	VLC	BL	DBr	AL	LAL	VLA	Clean
Grooves #1		100										95	5							
Grooves #2		100										100								
Oil #1										100										100
Crownland		20	35	40	5						5	75	20							
Land #2				100										90	10					
Land #3										100										100
Land #4										100										100

CRC Demerit Rating Summary

Piston Zone	1st Q	2nd Q	3rd Q	4th Q	Avg.
Grooves #1	31.3	51.3	50.0	48.8	45.3
Grooves #2	50.0	46.5	50.0	50.0	49.1
Oil #1	0.0	0.0	0.0	0.0	0.0
Crownland	37.3	32.8	25.3	47.5	35.7
Land #2	15.5	14.5	15.0	14.5	14.9
Land #3	0.0	0.0	0.0	0.0	0.0
Land #4	0.0	0.0	0.0	0.0	0.0

RATING SCALE

- HC - Heavy Carbon
- MC - Medium Carbon
- LC - Light Carbon
- VLC - Very Light Carbon
- BL - Black Lacquer
- DBr - Dark Brown Lacquer
- AL - Amber Lacquer
- LAL - Light Amber Lacquer
- VLA - Very Light Amber Lacquer

Appendix 2-3
AMTRAK B-20 TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE
GE Sludge Ratings

Cylinder # 2R

Location Percent Area and Depth

Crankcase Cover				Rocker Cover				Crankcase "A" Frame				Rocker Arms			
1/4A	100	D	0	1/4A	50	D	0	1/4A	0	D	0	1/4A	50	D	0
1/2A	0	E	0	1/2A	25	E	0	1/2A	100	E	0	1/2A	50	E	0
3/4A	0	F	0	3/4A	25	F	0	3/4A	0	F	0	3/4A	0	F	0
A	0	G	0	A	0	G	0	A	0	G	0	A	0	G	0
AB	0	H	0	AB	0	H	0	AB	0	H	0	AB	0	H	0
B	0	I	0	B	0	I	0	B	0	I	0	B	0	I	0
C	0	J	0	C	0	J	0	C	0	J	0	C	0	J	0
Merit 9.75				Merit 9.56				Merit 9.50				Merit 9.63			

Cylinder # 2L

Location Percent Area and Depth

Crankcase Cover				Rocker Cover				Crankcase "A" Frame				Rocker Arms			
1/4A	100	D	0	1/4A	50	D	0	1/4A	0	D	0	1/4A	50	D	0
1/2A	0	E	0	1/2A	25	E	0	1/2A	100	E	0	1/2A	50	E	0
3/4A	0	F	0	3/4A	25	F	0	3/4A	0	F	0	3/4A	0	F	0
A	0	G	0	A	0	G	0	A	0	G	0	A	0	G	0
AB	0	H	0	AB	0	H	0	AB	0	H	0	AB	0	H	0
B	0	I	0	B	0	I	0	B	0	I	0	B	0	I	0
C	0	J	0	C	0	J	0	C	0	J	0	C	0	J	0
Merit 9.75				Merit 9.56				Merit 9.50				Merit 9.63			

Appendix 3

Liner, Piston Ring, and Bearing Wear Worksheet

- Appendix 3-1: Cylinder Liner Measurements, Cylinder # 2R
- Appendix 3-2: GE Ring Measurements, Cylinder # 2R
- Appendix 3-3: GE Ring Measurements, Cylinder # 2L
- Appendix 3-4: GE Connecting Rod Bearing Inspection

Appendix 3-1
AMTRAK B-20 TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE
Cylinder Liner Measurements

Cylinder # 2R Liner Serial # LG09100823

Direction Relative to Crankshaft

Inches From Fire Face	Perpendicular					Inches From Fire Face	Parallel				
	Before Test	Taper	After Test	Taper	Wear		Before Test	Taper	After Test	Taper	Wear
1 1/2 ¹	9.0041	0.0021	9.0039	0.0027	-0.0002	1 1/2 ¹	9.0049	-0.0003	9.0039	0.0000	-0.0010
2 3/64	9.0049	0.0013	9.0045	0.0021	-0.0004	2 3/64	9.0041	0.0005	9.0039	0.0000	-0.0002
5	9.0066	-0.0004	9.0064	0.0002	-0.0002	5	9.0045	0.0001	9.0035	0.0004	-0.0010
8	9.0065	-0.0003	9.0064	0.0002	-0.0001	8	9.0043	0.0003	9.0026	0.0013	-0.0017
13 15/16 ²	9.0066	-0.0004	9.0071	-0.0005	0.0005	13 15/16 ²	9.0049	-0.0003	9.0044	-0.0005	-0.0005
15 3/8 ³	9.0062	0.0000	9.0066	0.0000	0.0004	15 3/8 ³	9.0046	0.0000	9.0039	0.0000	-0.0007

Cylinder # 2L Liner Serial # LG09100826

Direction Relative to Crankshaft

Inches From Fire Face	Perpendicular					Inches From Fire Face	Parallel				
	Before Test	Taper	After Test	Taper	Wear		Before Test	Taper	After Test	Taper	Wear
1 1/2 ¹	9.0037	0.0017	9.0048	0.0028	0.0011	1 1/2 ¹	9.0035	0.0012	9.0060	0.0001	0.0025
2 3/64	9.0045	0.0009	9.0058	0.0018	0.0013	2 3/64	9.0042	0.0005	9.0059	0.0002	0.0017
5	9.0060	-0.0006	9.0074	0.0002	0.0014	5	9.0047	0.0000	9.0056	0.0005	0.0009
8	9.0054	0.0000	9.0077	-0.0001	0.0023	8	9.0045	0.0002	9.0050	0.0011	0.0005
13 15/16 ²	9.0060	-0.0006	9.0080	-0.0004	0.0020	13 15/16 ²	9.0042	0.0005	9.0062	-0.0001	0.0020
15 3/8 ³	9.0054	0.0000	9.0076	0.0000	0.0022	15 3/8 ³	9.0047	0.0000	9.0061	0.0000	0.0014

New liner bore Min. 8.9980" Max wear limit 9.120"

¹ Top ring reversal

² Bottom ring travel

³ No wear reference point below ring travel

Bore standard used for measurements 9.000"

Comments: 2R - Light polish on Thrust side @ 6". Light polish at ring reversal, 360°. Amber deposits 2" down from fire face. Good cross hatching on rest of liner. Intake port dry/light carbon. Fire face - clean.
2L - Light polish at ring reversal, 360°. Amber deposits 2" down from fire face. Good cross hatching on rest of liner. Intake port wet/clean.
Fire face - light deposit around intake valve

Appendix 3-2
AMTRAK B-20 FIELD TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE
GE Ring Measurements

Cylinder FR861 R2

RING THICKNESS, in						
Ring #	Position	Tip	90°	180°	270°	Tip
1	Before	0.1863	0.1864	0.1863	0.1863	0.1862
	After	0.1849	0.1852	0.1853	0.1853	0.1852
	Decrease	0.0014	0.0012	0.0010	0.0010	0.0010
2	Before	0.1176	0.1177	0.1170	0.1177	0.1180
	After	0.1173	0.1173	0.1171	0.1171	0.1171
	Decrease	0.0003	0.0004	-0.0001	0.0006	0.0009

RADIAL WIDTH, in						
Ring #	Position	Tip	90°	180°	270°	Tip
1	Before	0.3019	0.3020	0.3024	0.3019	0.3007
	After	0.3010	0.3023	0.3024	0.3014	0.3000
	Decrease	0.0009	-0.0003	0.0000	0.0005	0.0007
2	Before	0.3039	0.3039	0.3043	0.3045	0.3042
	After	0.3032	0.3032	0.3033	0.3034	0.3032
	Decrease	0.0007	0.0007	0.0010	0.0011	0.0010

RING END GAP, in			
Ring #	1	2	Oil
Before	0.057	0.086	0.000
After	0.056	0.086	0.000
Increase	-0.001	0.000	0.000

RING WEIGHT, grams			
Ring #	1	2	Oil
Before	165.40	102.50	0.00
After	164.87	102.20	0.00
Decrease	0.53	0.30	0.00

SIDE CLEARNCE, in (missed)			
Ring #	1	2	Oil
Before	0.0000	0.0000	0.0000
After	0.0000	0.0000	0.0000
Increase	0.0000	0.0000	0.0000

Appendix 3-3
AMTRAK B-20 FIELD TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE
GE Ring Measurements

Cylinder FR861 L2

RING THICKNESS, in						
Ring #	Position	Tip	90°	180°	270°	Tip
1	Before	0.1859	0.1859	0.1859	0.1858	0.1859
	After	0.1852	0.1849	0.1850	0.1851	0.1852
	Decrease	0.0007	0.0010	0.0009	0.0007	0.0007
2	Before	0.1173	0.1174	0.1174	0.1174	0.1174
	After	0.1171	0.1170	0.1170	0.1170	0.1170
	Decrease	0.0002	0.0004	0.0004	0.0004	0.0004

RADIAL WIDTH, in						
Ring #	Position	Tip	90°	180°	270°	Tip
1	Before	0.3016	0.3023	0.3031	0.3031	0.3020
	After	0.3012	0.3022	0.3025	0.3024	0.3014
	Decrease	0.0004	0.0001	0.0006	0.0007	0.0006
2	Before	0.3038	0.3035	0.3036	0.3035	0.3037
	After	0.3033	0.3038	0.3037	0.3031	0.3031
	Decrease	0.0005	-0.0003	-0.0001	0.0004	0.0006

RING END GAP, in			
Ring #	1	2	Oil
Before	0.053	0.086	0.000
After	0.052	0.086	0.000
Increase	-0.001	0.000	0.000

RING WEIGHT, grams			
Ring #	1	2	Oil
Before	165.30	102.10	0.00
After	164.73	101.92	0.00
Decrease	0.57	0.18	0.00

SIDE CLEARNCE, in (missed)			
Ring #	1	2	Oil
Before	0.0000	0.0000	0.0000
After	0.0000	0.0000	0.0000
Increase	0.0000	0.0000	0.0000

Appendix 3-4
AMTRAK B-20 TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE
GE Connecting Rod Bearing Inspection

Description of Bearing Condition

Bearing	Rod Journal # 2
Top	Appearance of even/normal loading. Good/serviceable condition 50% Flashing remover, no copper showing Light dirt scratching, and small pitting in flashing overlay
Bottom	Appearance of even/normal loading. Good/serviceable condition 70% Flashing removed, no overlay removed and no copper showing 2% Cavitation wear @ oil gallery, and small pitting in flashing overlay

Appendix 4

Used Oil Data and Charts

- Appendix 4-1: Used Oil Analysis
- Appendix 4-2: Viscosity Increase
- Appendix 4-3: Base and Acid Number
- Appendix 4-4: LMOA Pentane Insolubles
- Appendix 4-5: Oxidation
- Appendix 4-6: Copper
- Appendix 4-7: Iron
- Appendix 4-8: Lead

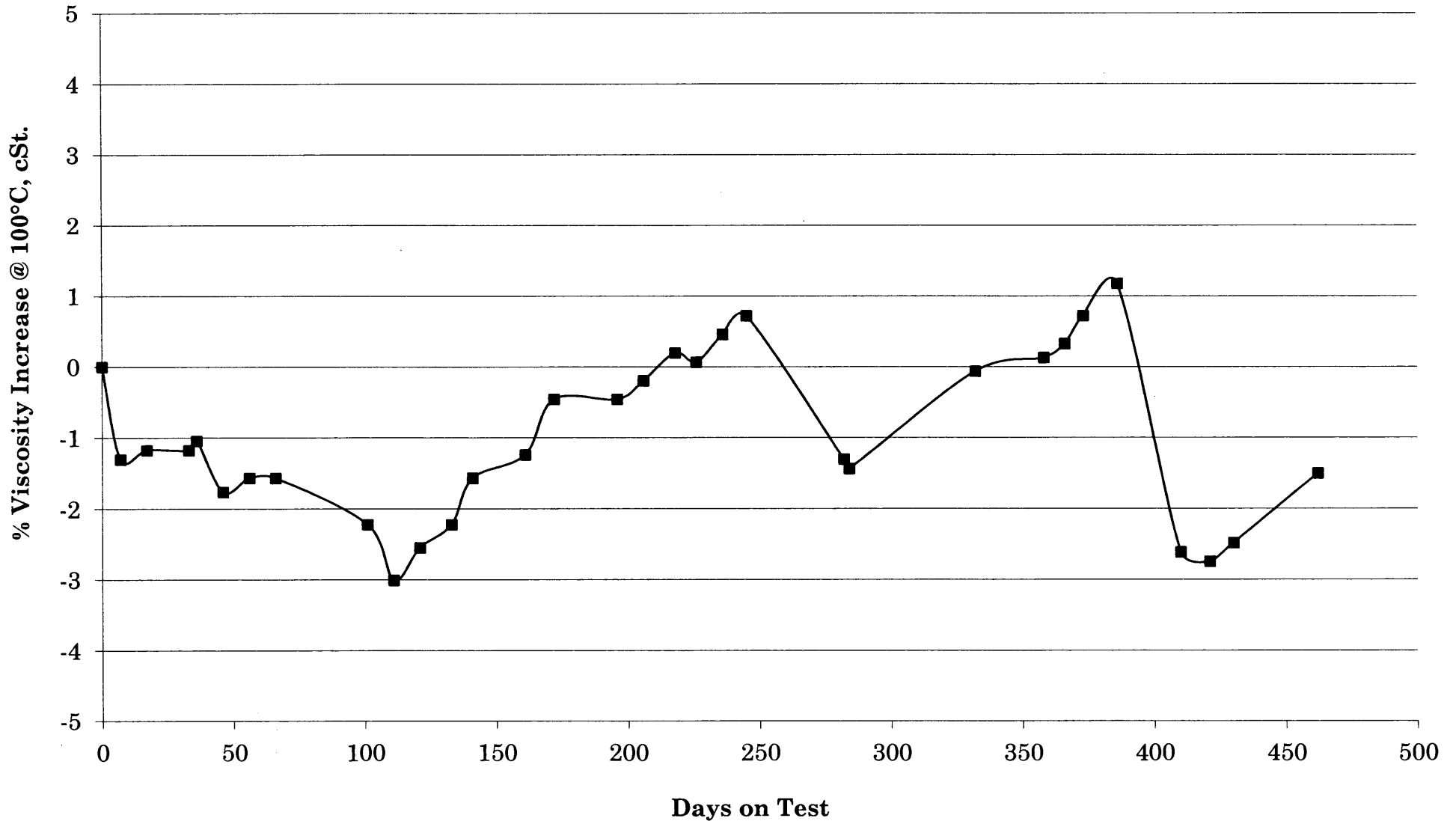
Appendix 4-1
USED OIL ANALYSIS
Unit 500

Amtrak Bio Diesel Test

Date	Engine	Vis	% Vis. Inc.	TBN	TAN	CPI	DIR				ICP SPECTRO ppm										Fuel Dilution	Bio Content		
Sampled	Days	100°C	100°C	D4739	D664	LMOA	Oxi	Nit	Sulf	Soot	B	Ca	Cr	Cu	Fe	Mo	Na	P	Pb	Si	Sn	Zn	%	%
03/01/10	0	15.3	0.00		0	0	0	0	0	0	0			0	0				0	5	<2.0	<2.0	0.0	0.0
03/08/10	7	15.10	-1.31	10.73	1.9	0.92	5	1	15	0.08	1	4964	<1.0	1	5	99	<10.0	20	1	5	<2.0	<2.0	<1	<.5
03/18/10	17	15.12	-1.18	9.94	2.0	0.99	5	1	14	0.10	1	4744	<1.0	1	6	95	<10.0	29	1	5	<2.0	<2.0	<1	<.5
04/03/10	33	15.12	-1.18	9.43	2.8	1.25	7	1	18	0.15	1	4822	<0.5	1	7	96	<5.0	27	1	4	<1.0	1	<1	<.5
04/06/10	36	15.14	-1.05	9.32	3.0	1.49	8	1	19	0.16	1	4886	<0.5	1	8	96	<5.0	30	1	4	<1.0	<1.0	<1	<.5
04/16/10	46	15.03	-1.76	8.53	2.7	1.55	7	1	19	0.18	1	4654	<0.4	1	8	92	<4.0	37	0	5	<0.8	<0.4	<1	<.5
04/26/10	56	15.06	-1.57	8.29	2.6	1.53	9	1	22	0.22	1	4824	<0.5	1	10	93	<5.0	35	1	5	<1.0	<1.0	<1	<.5
05/06/10	66	15.06	-1.57	8.01	3.3	1.59	8	1	19	0.21	1	4412	<0.5	1	9	90	<5.0	39	1	5	<1.0	<1.0	<1	<.5
06/10/10	101	14.96	-2.22	12.30	1.8	0.67	3	0	9	0.06	12	5730	<0.46	0	4	107	<4.62	9	<0.46	13	<0.92	1	<1	<.5
06/20/10	111	14.84	-3.01	10.10	2.0	0.86	4	1	11	0.10	11	5310	<0.45	0	4	100	<4.50	19	<0.45	3	<0.90	1	<1	<.5
06/30/10	121	14.91	-2.55	9.62	2.7	1.29	6	1	17	0.14	10	5169	<0.48	0	5	99	<4.76	18	<0.48	3	<0.95	2	<1	<.5
07/12/10	133	14.96	-2.22	10.40	2.7	1.03	6	1	16	0.11	8	5067	<0.46	0	6	97	<4.57	28	<0.46	3	<0.91	<0.46	<1	<.5
07/20/10	141	15.06	-1.57	10.00	3.0	1.46	8	1	21	0.22	6	5040	<0.48	0	7	94	<4.81	24	<0.48	3	<0.96	<0.48	<1	<.5
08/09/10	161	15.11	-1.24	9.19	2.9	1.86	8	1	21	0.20	7	4857	<0.47	1	7	95	<4.73	36	<0.47	4	<0.95	<0.67	<1	<.5
08/20/10	172	15.23	-0.46	8.67	2.8	1.46	8	1	20	0.22	6	4652	<0.43	0	8	92	<4.30	44	<0.43	3	<0.86	<0.46	<1	<.5
09/13/10	196	15.23	-0.46	9.04	3.3	1.95	9	1	23	0.22	6	4890	<0.51	0	8	98	<5.09	39	<0.51	3	<1.02	<1.24	1.2	<.5
09/23/10	206	15.27	-0.20	8.68	2.0	1.55	11	1	26	0.27	6	4995	<0.52	0	9	98	<5.19	38	1	3	<1.04	1	<1.0	<0.5
10/05/10	218	15.33	0.20	8.36	2.5	1.97	13	1	31	0.32	6	5076	<0.48	1	11	99	<4.82	39	<1.27	3	<0.96	1	<1.0	0.7
10/13/10	226	15.31	0.07	8.08	3.5	2.6	11	2	28	0.30	5	4705	<0.46	1	10	94	<4.60	43	<0.46	4	<0.92	1	<1.0	0.6
10/23/10	236	15.37	0.46	7.62	2.7	2.37	10	1	25	0.27	4	4570	<0.48	1	10	91	<4.80	47	<0.48	3	<0.96	1	<1.0	0.6
11/01/10	245	15.41	0.72	7.37	3.0	2.5	11	1	28	0.33	4	4538	<0.51	1	12	90	<5.12	46	<1.39	3	<1.02	<0.51	1.2	0.6
12/08/10	282	15.10	-1.31	14.10	2.2	0.7	4	0	9	0.06	1	6029	<0.42	0	4	111	<4.18	13	<0.42	2	<0.84	<0.42	2.5	<.5
12/10/10	284	15.08	-1.44	13.60	2.4	0.7	5	1	12	0.08	1	6185	<0.47	0	2	109	<4.71	14	<0.63	3	<0.94	<0.47	2.5	<.5
01/27/11	332	15.29	-0.07	11.90	3.4	0.92	9	1	21	0.18	1	5893	<0.50	0	7	110	<4.97	16	<1.659	3	<0.99	<0.86	3.0	<.5
02/22/11	358	15.32	0.13	10.14	4.2	1.61	9	1	19	0.19	1	5260	<0.46	0	7	100	<4.61	36	<0.61	3	<0.92	<0.68	1.2	<.5
03/02/11	366	15.35	0.33	10.64	4.0	2.18	10	1	22	0.24	1	5221	<0.48	0	7	100	<4.85	34	<0.48	3	<0.97	1	1.1	<0.5
03/09/11	373	15.41	0.72	9.57	3.6	1.92	11	1	25	0.26	1	5306	<0.45	0	9	100	<4.46	37	<0.91	3	<0.89	<0.45	<1.0	0.5
03/22/11	386	15.48	1.18	9.12	3.6	2.06	11	1	27	0.29	1	5181	<0.48	0	10	99	<4.82	39	<0.48	3	<0.96	<0.48	<1.0	0.5
04/15/11	410	14.90	-2.61	14.20	1.5	0.51	3	0	6	0.01	1	5900	<0.44	0	3	115	<4.39	19	<0.44	5	<0.88	1	1.3	<0.5
04/26/11	421	14.88	-2.75	13.70	1.8	0.53	3	0	9	0.07	1	5909	<0.46	0	1	114	<4.60	20	<0.46	4	<0.92	<0.46	1.9	<.5
05/05/11	430	14.92	-2.48	13.10	2.1	0.83	5	0	13	0.11	1	5879	<0.49	0	4	115	<4.87	20	<0.49	4	<0.97	<0.49	2.0	<.5
06/06/11	462	15.07	-1.50	12.90	1.61	1	6	1	16	0	0.5	5991	<0.50	0	5	114	<4.98	18	<0.50	4	<1.00	<0.50	1.7	<.5

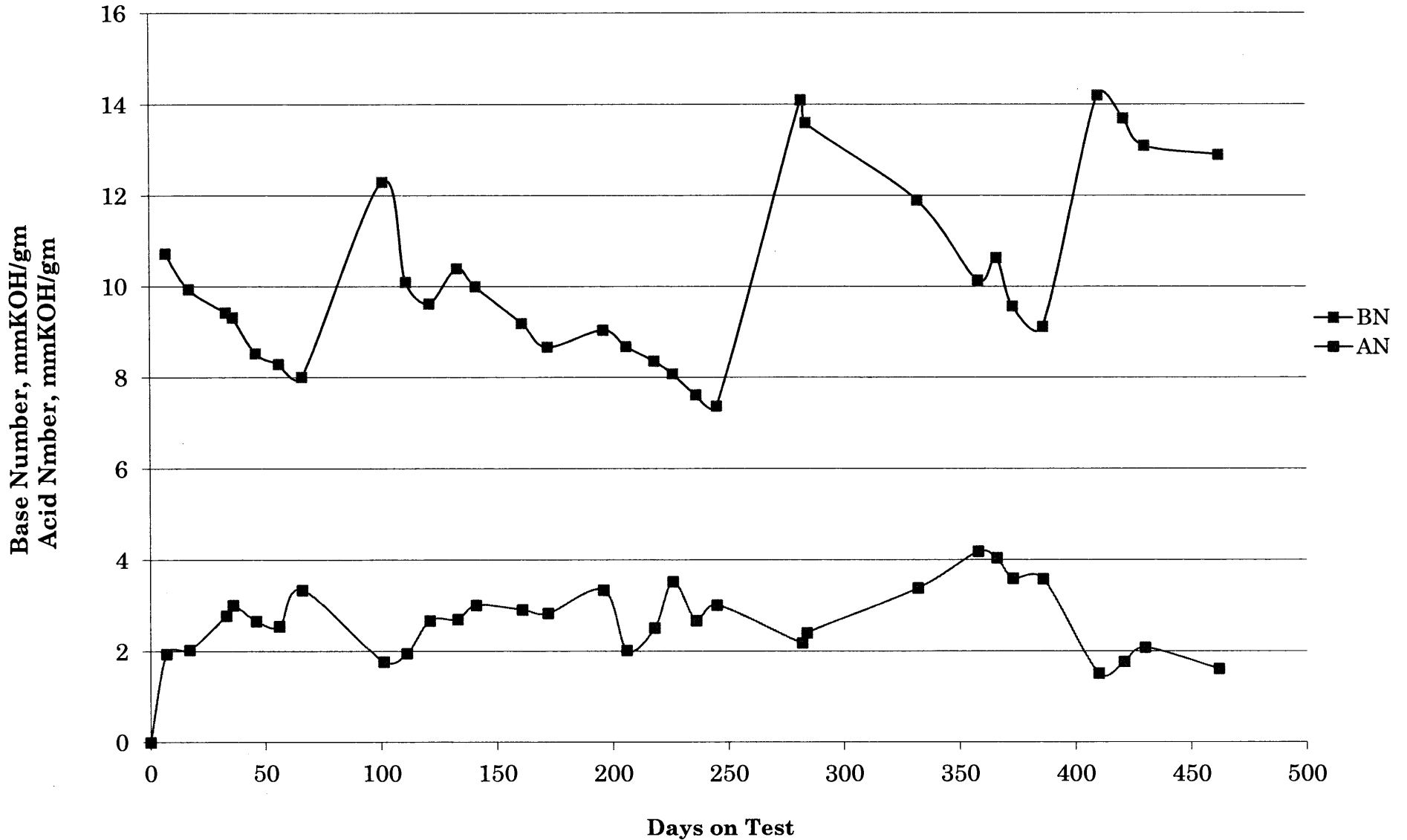
Possible oil change based on rise in BN, drop in AN and PI

Appendix 4-2
FR-861 Amtrak B-20 Test
Unit 500
Viscosity Increase

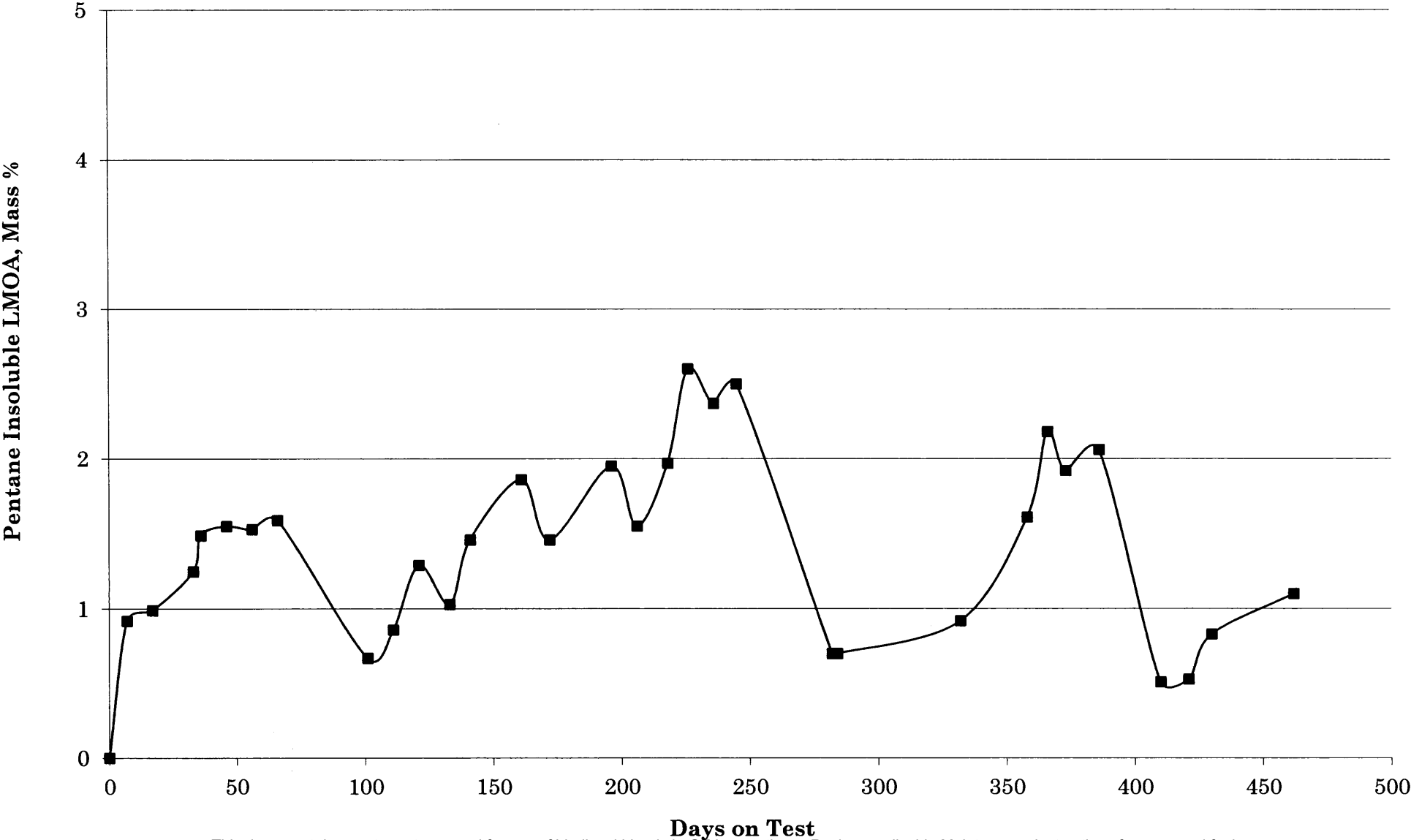


This document does not grant approval for use of biodiesel blends in GE locomotives. Review applicable Maintenance Instructions for approved fuels.

Appendix 4-3
FR-861 Amtrak B-20 Test
Unit 500
Base and Acid Number

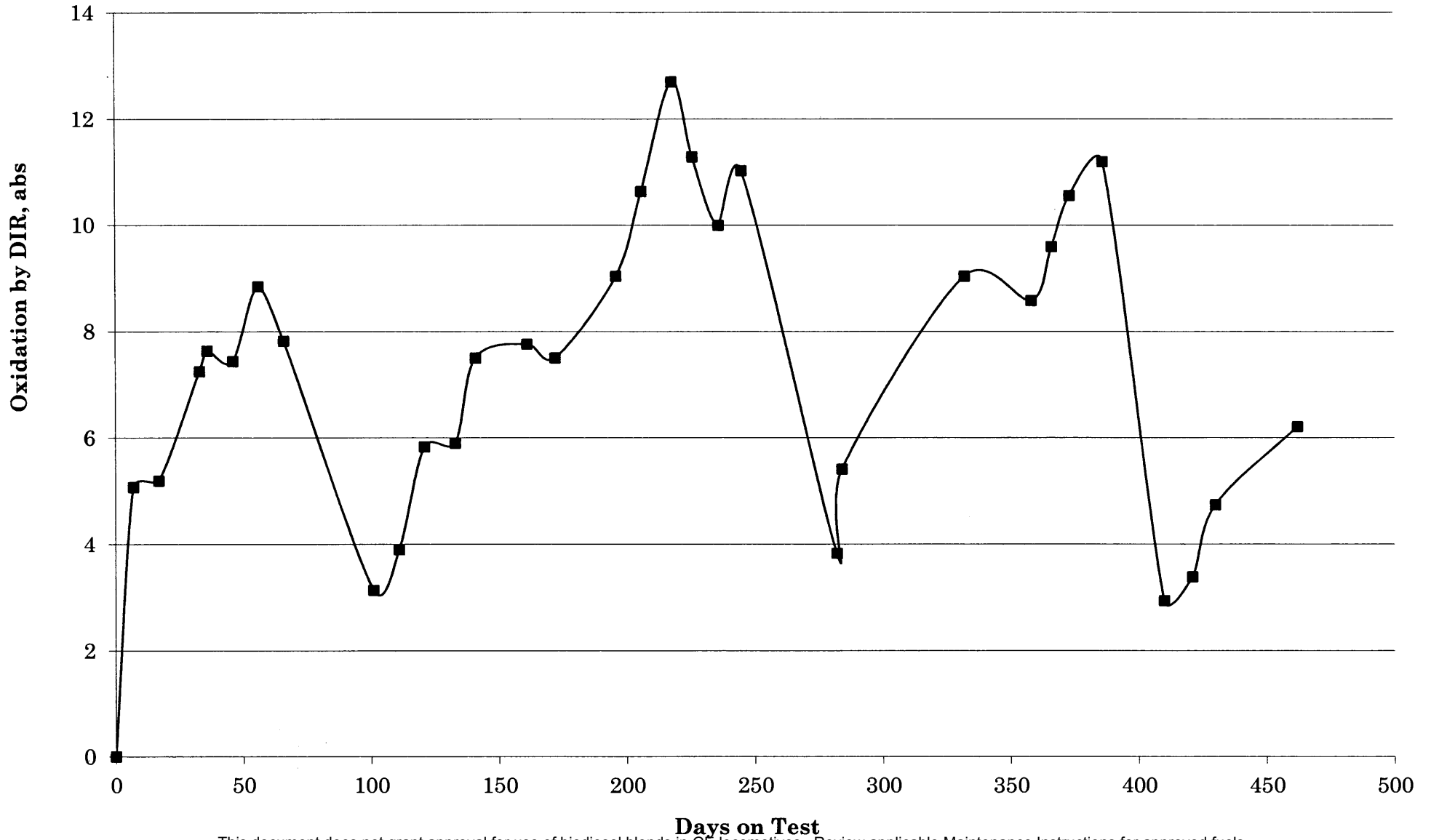


Appendix 4-4
FR-861 Amtrak B-20 Test
Unit 500
LMOA Pentane Insolubles

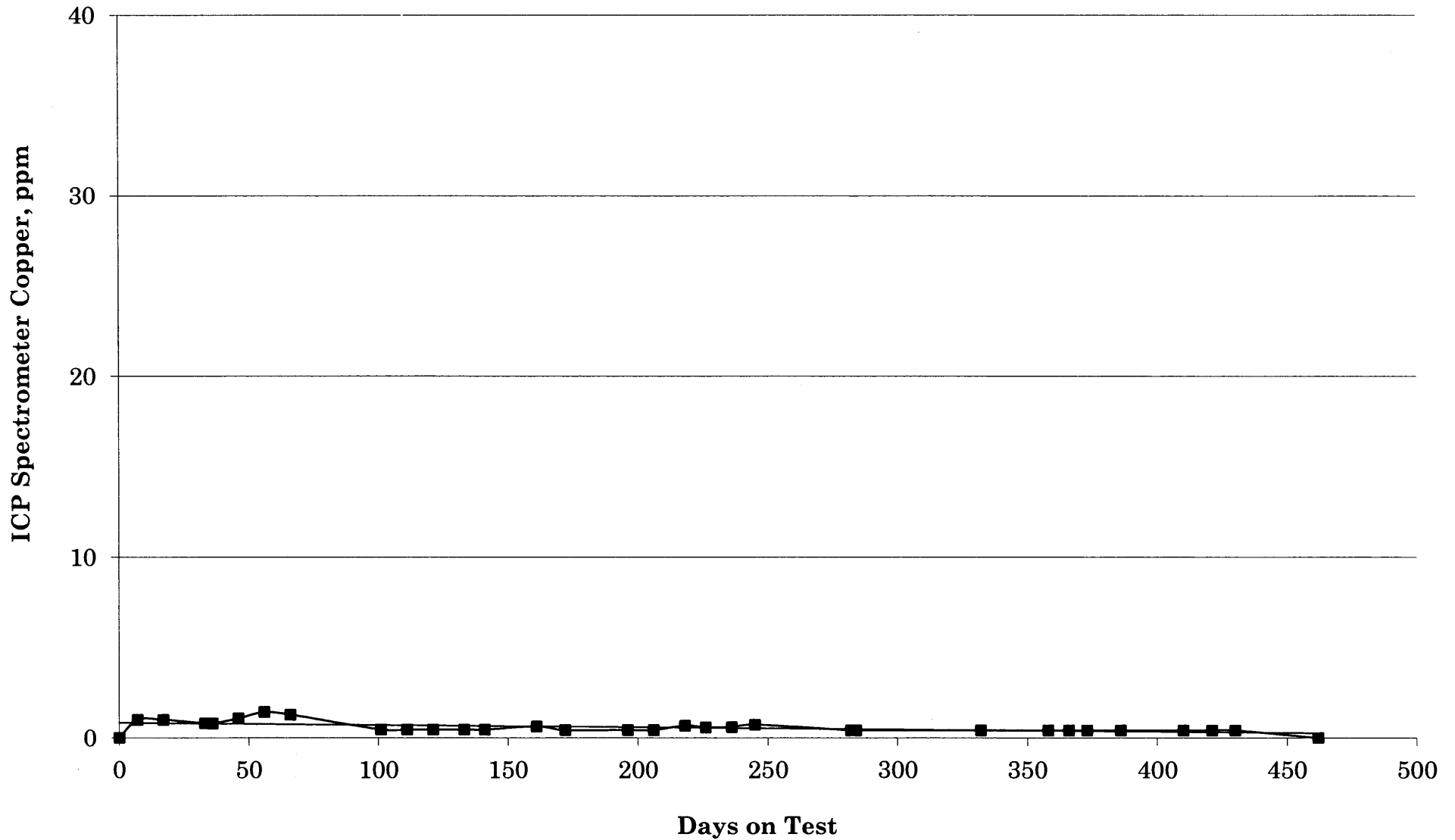


This document does not grant approval for use of biodiesel blends in GE locomotives. Review applicable Maintenance Instructions for approved fuels.

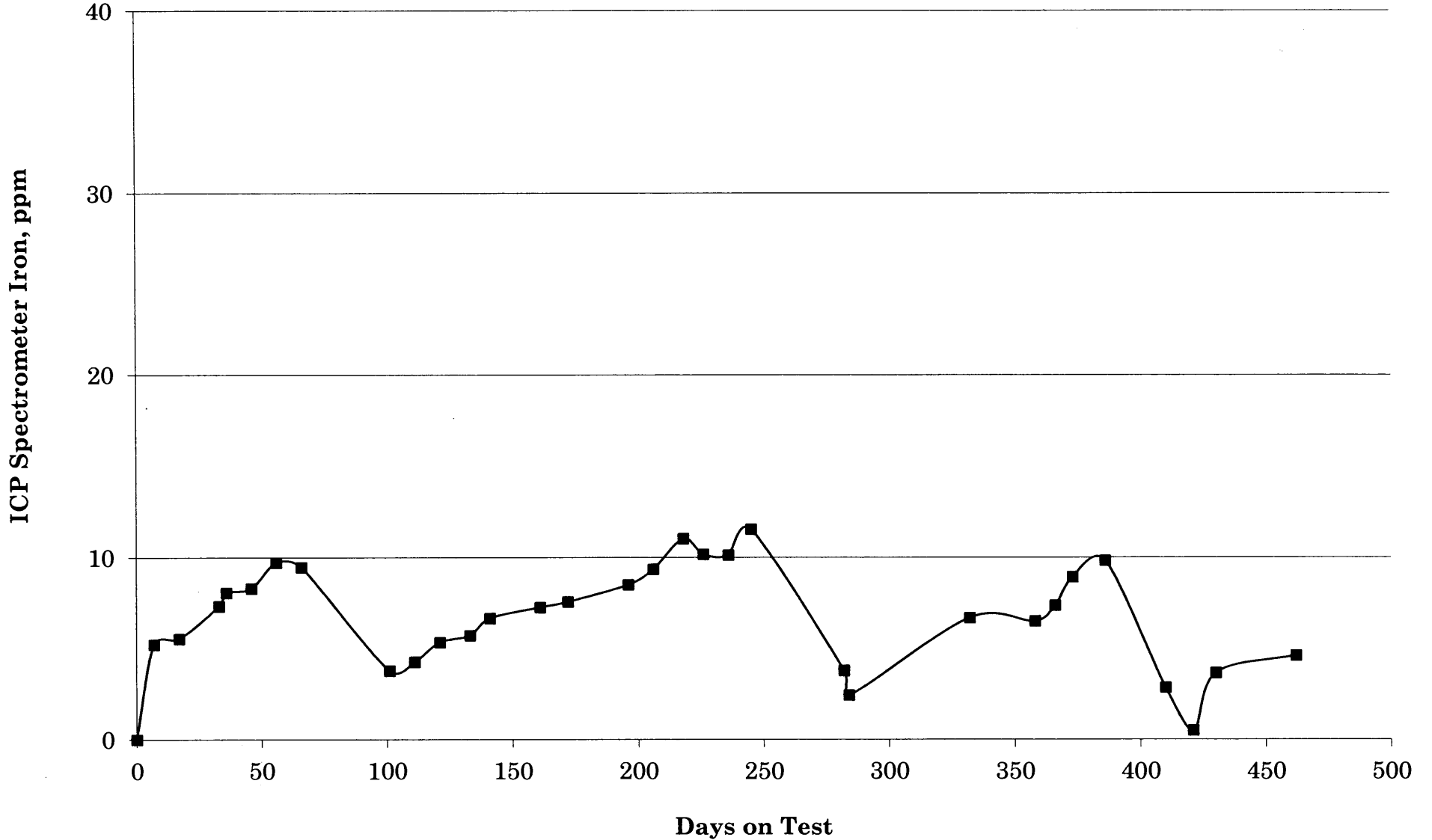
Appendix 4-5
FR-861 Amtrak B-20 Test
Unit 500
Oxidation



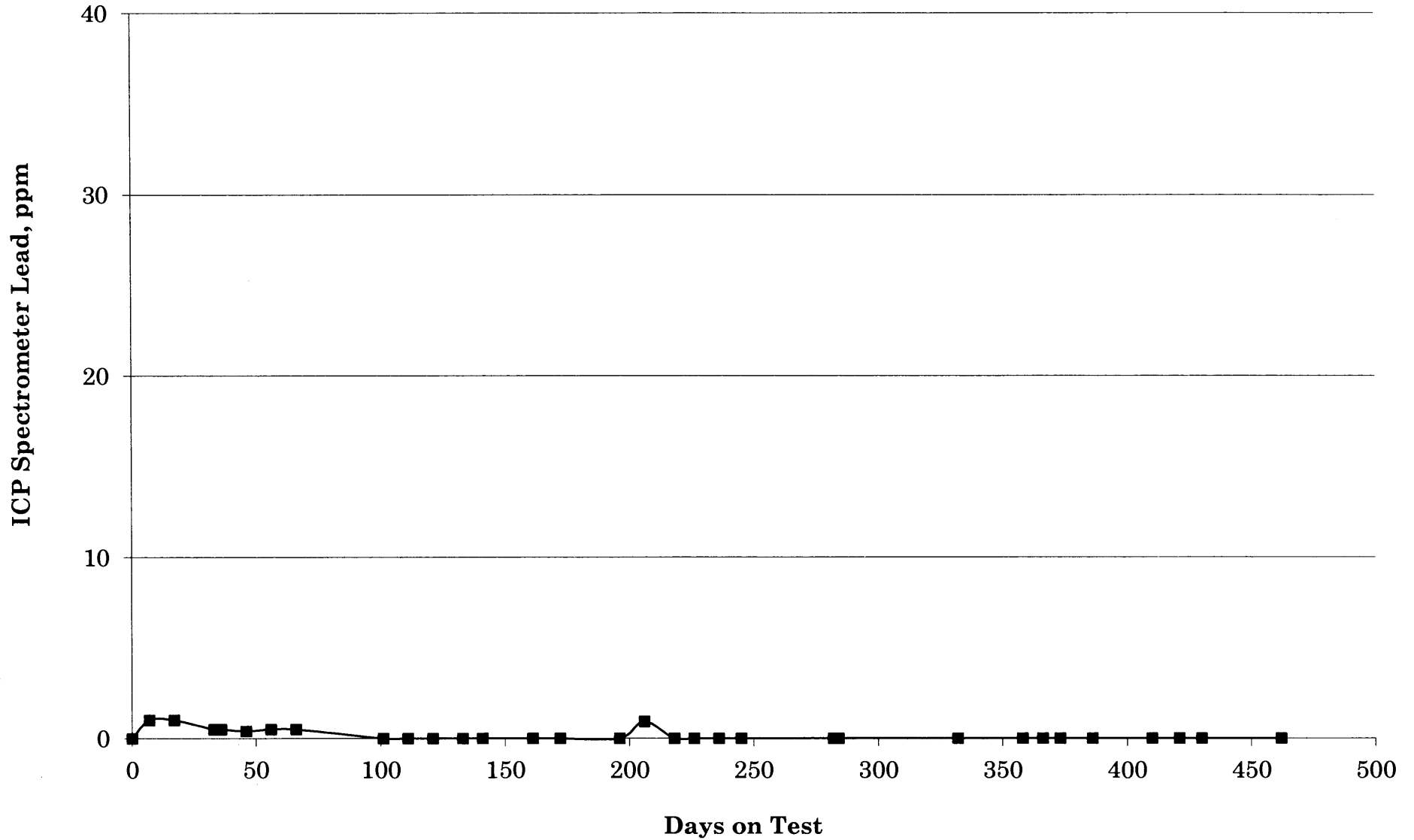
Appendix 4-6
FR-861 Amtrak B-20 Test
Unit 500
Copper



Appendix 4-7
FR-861 Amtrak B-20 Test
Unit 500
Iron



Appendix 4-8
FR-861 Amtrak B-20 Test
Unit 500
Lead



This document does not grant approval for use of biodiesel blends in GE locomotives. Review applicable Maintenance Instructions for approved fuels.

Appendix 5

Photographs

- Appendix 5-1: Pistons (Thrust)
- Appendix 5-2: Pistons
- Appendix 5-3: Rockers
- Appendix 5-4: Rocker Covers
- Appendix 5-5: Crankcase Covers
- Appendix 5-6: Liners
- Appendix 5-7: Injectors
- Appendix 5-8: Rings
- Appendix 5-9: Bearing (Top and Bottom)

Appendix 5-1
AMTRAK B-20 FIELD TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE



Piston 2R (thrust)

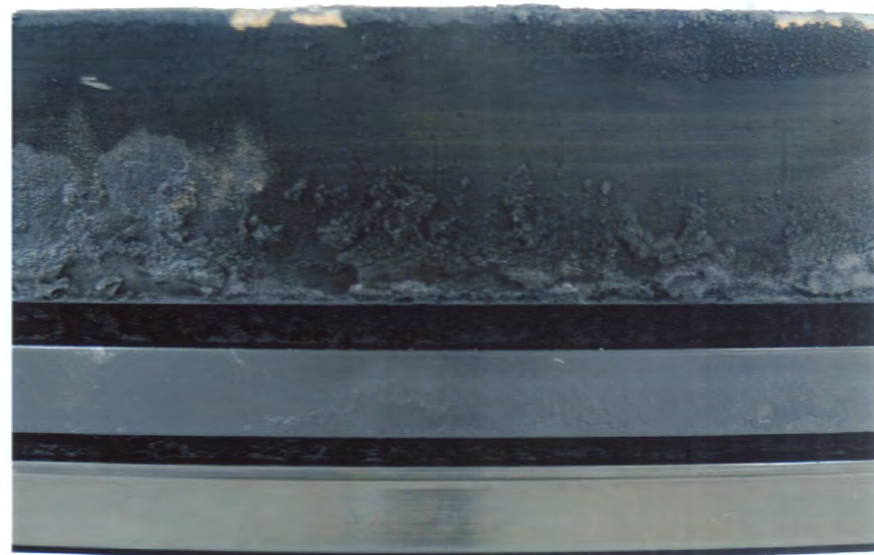


Piston 2L (thrust)

Appendix 5-2
AMTRAK B-20 FIELD TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE

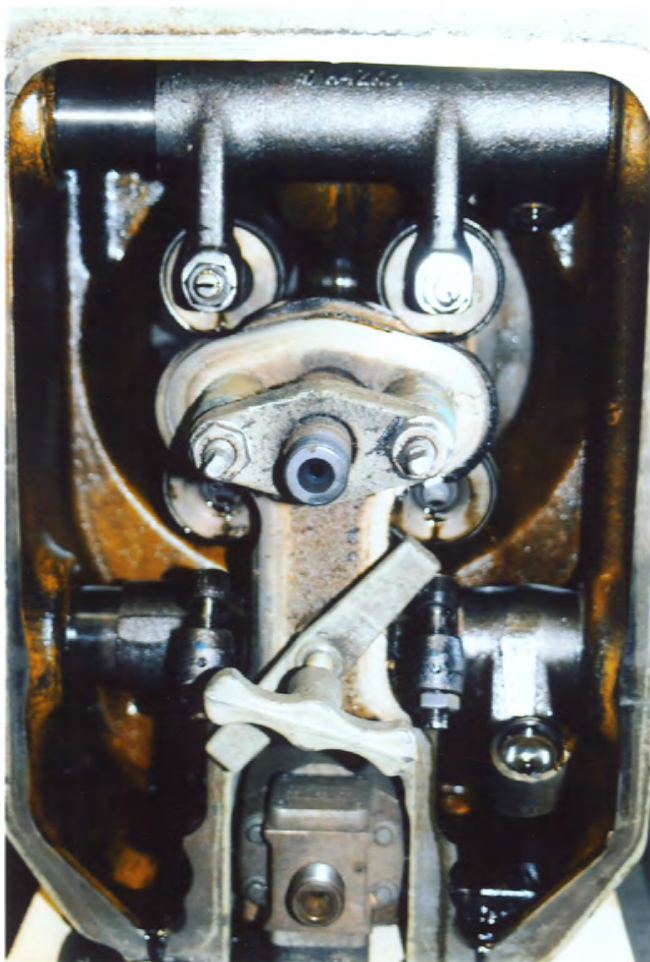


Piston 2R (RBZ#4)

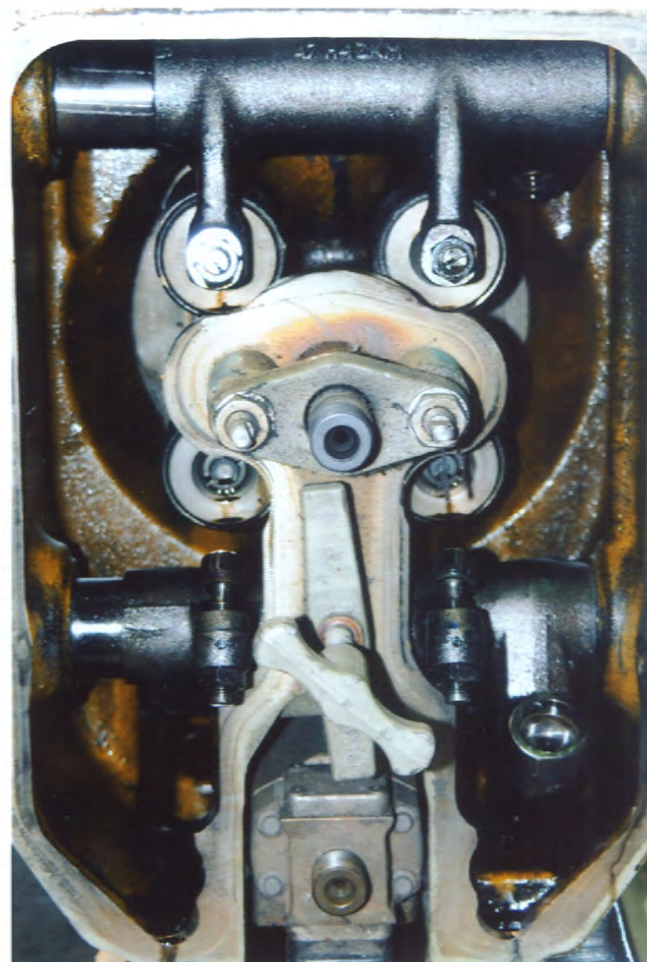


Piston 2L (RBZ#4)

Appendix 5-3
AMTRAK B-20 FIELD TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE

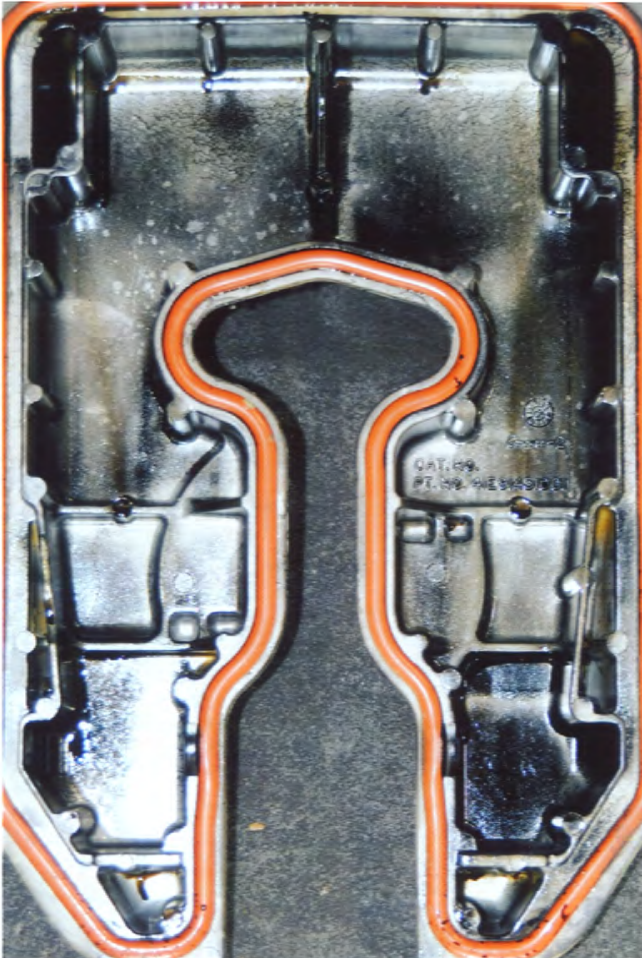


Rockers 2R



Rockers 2L

Appendix 5-4
AMTRAK B-20 FIELD TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE



Rocker Cover 2R



Rocker Cover 2L

Appendix 5-5
AMTRAK B-20 FIELD TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE

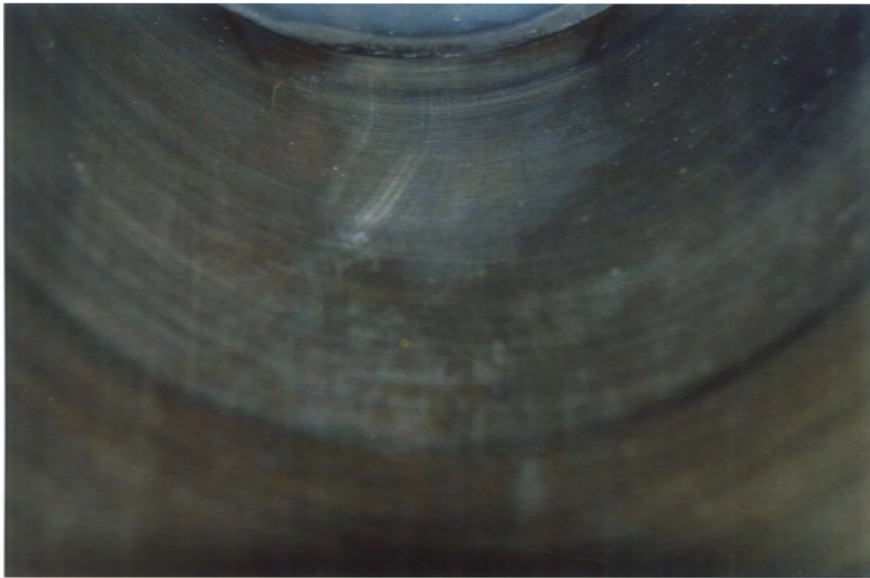


Crankcase Cover 2R

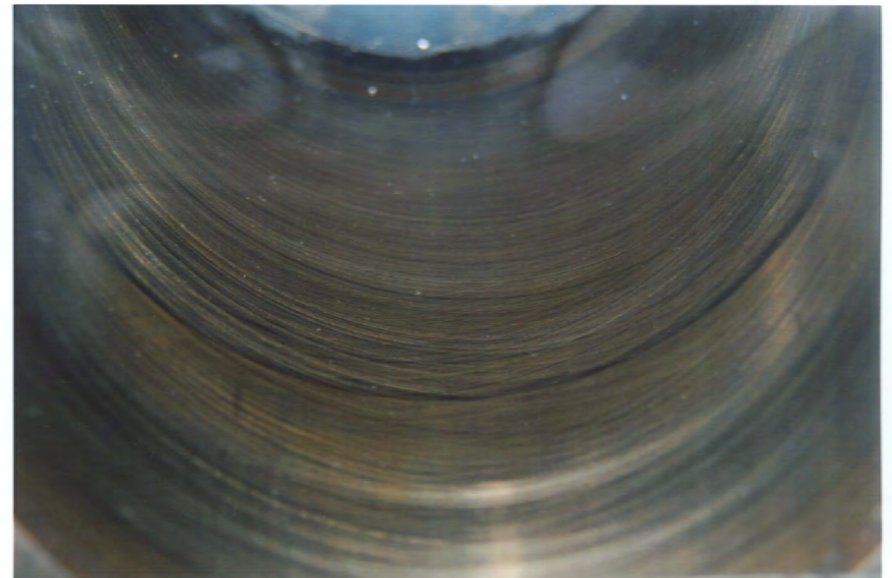


Crankcase Cover 2L

Appendix 5-6
AMTRAK B-20 FIELD TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE



Liner 2R



Liner 2L

Appendix 5-7
AMTRAK B-20 FIELD TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE

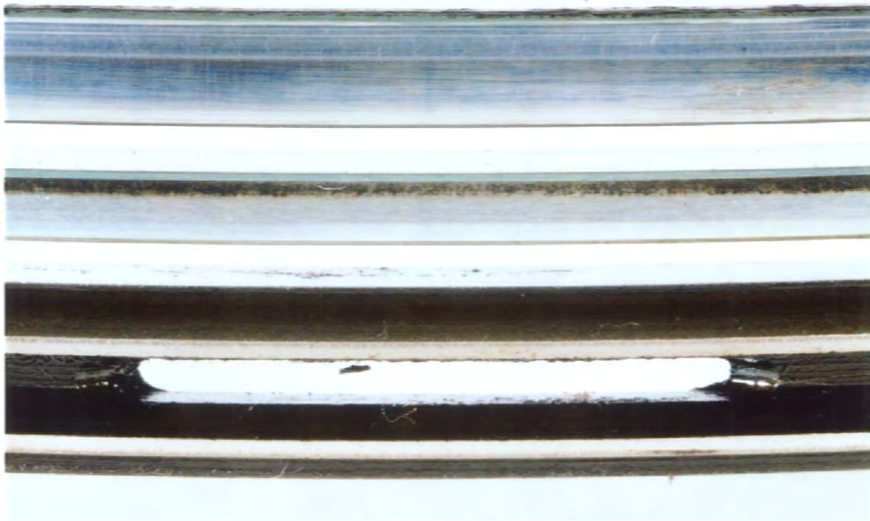


Injector 5R



Injector 5L

Appendix 5-8
AMTRAK B-20 FIELD TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE

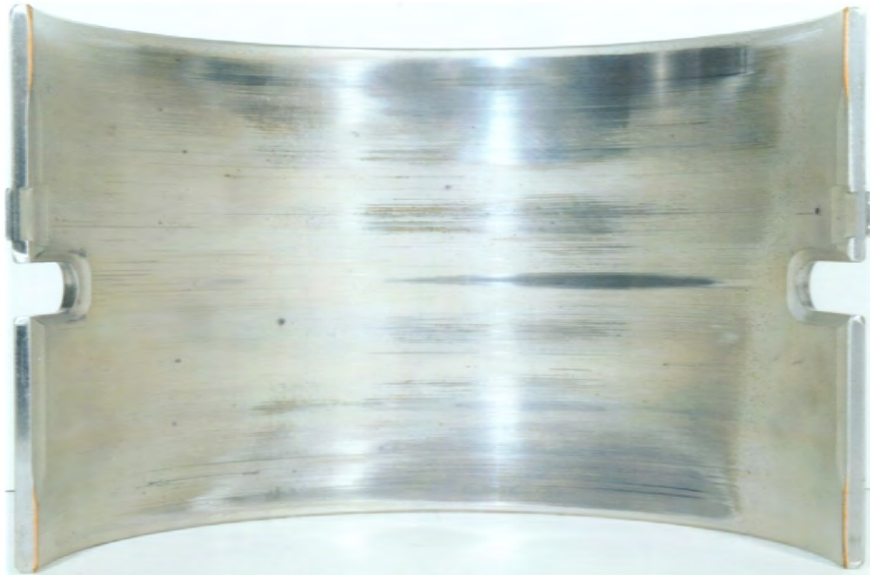


**Rings 2R
Face**

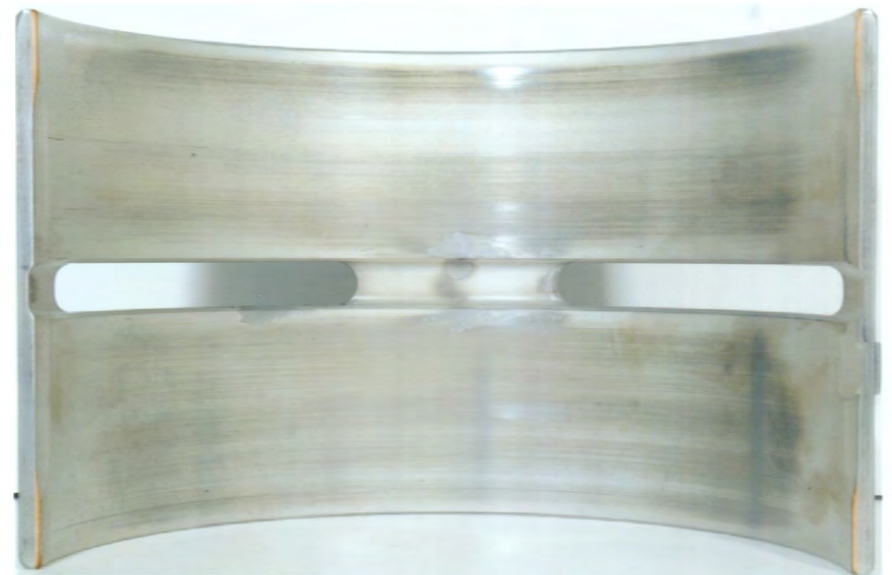


**Rings 2R
Backside**

Appendix 5-9
AMTRAK B-20 FIELD TEST - FR861
ORONITE TECHNOLOGY
UNIT 500 GE P32-8 7FDL-12 LOCOMOTIVE



Bearing Top



Bearing Bottom