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**FPC[®] FUEL CATALYST TEST
FUEL EFFICIENCY, EMISSIONS REDUCTION,
AND ENGINE CLEANLINESS STUDY**

BY

**CANADIAN PACIFIC RAILWAY/
ST. LAWRENCE & HUDSON RAILWAY**



Report prepared
by
FPC Technology, Inc.
Boise, Idaho

May 1, 2000

This report documents the effect of FPC-2™ (Fuel Performance Catalyst) treatment upon engine fuel efficiency, Greenhouse Gas emissions (CO₂, CH₄, N₂O, HC, & CO) reduction, and exhaust smoke reduction. A Carbon Mass Balance (CMB) test, Bacharach True-Spot smokespot measurements, and digital camera pictures were performed on eight Canadian Pacific Railway/St Lawrence & Hudson Railway (CPR/St L&H) locomotive engines. It documents the effect of FPC-2™ upon carbon removal on piston crowns, rings and exhaust stacks. EMD engines powered the 6 SD40-2's and 2 GP9's tested. To make the test more complete, Applied Environmental Sciences, Inc., Madison, WI was commissioned to take the data obtained from the CPR/St L&H CMB test and calculate the **Greenhouse Gas Emissions** reduction for CPR's fleet. Applied Environmental Sciences, Inc. is one of the most renowned & reputable companies in the Environmental Sciences industry.

One of the primary issues that FPCT wants to show CPR by using FPC® Catalyst in addition to fuel and maintenance savings, is the **Greenhouse Gas Emissions Reduction**. In today's industrial world, one of the key concerns is global climate change resulting from increasing levels of greenhouse gases.

The method of determining fuel consumption and emissions output is known as the Carbon Mass Balance (CMB), and is an adaptation of the EPA standardized Federal Test Procedures, which also uses CMB for fuel consumption and engine emissions determination. The engines were loaded using self-load. CPR/St L&H engine and electrical technicians helped collect engine and power data. Three SD40-2's were first tested under load at throttle notch positions 2, 4, 6, and 8 using untreated (baseline) fuel. The same three SD40-2's were then treated with FPC-2™, a fuel combustion catalyst, and operated as normal for over 500 operating hours. The average duty cycle on these hump yard units was approximately notch 2, which is quite low. The fleet was then re-tested with FPC-2™ treated fuel, while reproducing all engine and power output conditions.

The three-treated SD40-2's (Units #5476, #5477, and #5480). Units #5476 and #5477 were tested in notches 2, 4, 6, & 8. Unit #5480 amperage and voltage readings could not be reproduced between the baseline and treated test readings and was tested only at notch 8.

The three SD40-2's were also smoke spot tested with the Bacharach True-Spot Smoke tester in notches 2, 4, 6, & 8. Again, Unit #5480 could be smoke spot tested in notch 8 only. The remaining treated locomotives were not CMB or smoke tested because they were not equipped with self-load and a load box was not available.

The third element of the test consisted of digital camera pictures of the car body roof, exhaust stacks, piston crowns, and piston rings through the air-box ports. Pictures were taken of the piston crowns and piston rings in various cylinders and cylinder positions during the Baseline Test and during the Treated Test. Extreme care was taken to make sure the pistons were in the same position during the Treated portion of test as they were during the Baseline portion. These detailed pictures show the significant removal of hard carbon on the piston crowns, piston walls between rings, rings, and exhaust stacks. It was decided by CPR/St L&H test supervisor to take identical pictures of two additional SD40-2's that were not in the Baseline Test, so comparisons could be made to the treated units. These locomotives were not treated with FPC-2™.

Element four of the test consisted of determining the reduction of greenhouse gases (that trap heat in the

Earth's atmosphere) CPR can expect by using FPC[®] Catalyst. To obtain that reliable and accurate information FPCT commissioned Applied Environmental Sciences, Inc., Madison, WI to analyze the greenhouse gas information from the CPR/St L&H CMB test data.

A summary of the results are as follows:

- (1) **FUEL CONSUMPTION REDUCTION:**
Fuel consumption was reduced 5.1% to 9.5%, depending upon throttle setting. The overall fuel consumption reduction for the test fleet was 7.2% with FPC-2[™] treatment.
- (2) Exhaust smoke density was reduced 3.6% to 19.2%. **Smoke density reductions averaged 11.3% for the entire fleet at all throttle settings**, well below all other test averages of previous tests. This is attributed to the relative low duty cycle of the test units, which slowed the conditioning effect of the catalyst. Also, periods of heavy rain during the baseline test were a factor.
- (3) Piston crowns and rings were observed to be much cleaner with stacks much cleaner and drier after FPC-2[™] treatment
- (4) **GREENHOUSE GAS REDUCTION for CPR's total fleet tons/year:**
 - (a) **Reduction in Carbon Dioxide (CO₂)** **102,375 metric t/yr.**
 - (b) **Reduction in Methane (CH₄)** **5.6 metric t/yr.**
 - (c) **Reduction in Nitrous Oxide (N₂O)** **41.8 metric t/yr.**
 - (d) **Reduction in Hydrocarbons (HC)** **average 33.4%.**
 - (e) **Reduction in Carbon Monoxide (CO)** **average 34.1%.**

These benefits are supported by several laboratory tests, including Southwest Research Institute's (SwRI) test of a 12 cylinder, 645E3B using the Association of American Railroads Recommended Practice 503 (RP-503). Other test data reviewed in this report include findings of the Western Australia Institute of Technology (WAIT) and several power generating operations (gensets) where specific fuel consumption tests have been possible. These studies verify FPC-2[™] is most effective when used in engines operating under conditions that more closely approach the transient duty cycle of typical field operation.

The findings of the Canadian Pacific Railway/St. Lawrence & Hudson Railway test of the FPC-2[™] catalyst are also supported by findings of a number of other loadbox tests recently conducted by other railroads.

Table III

**Canadian Pacific Railway
Eastern Network
St. Lawrence & Hudson Railway
FUEL MASS FLOW RATES (gr./sec.) BY UNIT**

<u>UNIT NO.</u>	<u>NOTCH</u>	<u>BASELINE MASS (g/s)</u>	<u>FPC TREATED MASS (g/s)</u>	<u>PERCENT IMPROVEMENT</u>
5476	2	16.147	14.772	8.5%
5476	4	35.109	32.069	8.7%
5476	6	55.238	50.028	9.4%
5476	8	83.596	79.210	5.2%
			Average	8.0%
5477	2	17.415	15.870	8.9%
5477	4	41.778	39.075	6.5%
5477	6	70.481	66.309	5.9%
5477	8	90.501	85.826	5.2%
			Average	6.6%
5480	2	18.200	N/A	N/A
5480	4	45.967	N/A	N/A
5480	6	73.161	N/A	N/A
5480	8	90.249	83.792	7.2%
			Average	7.2%
FLEET AVERAGE =				7.2%

Notes: (1) Unable to reproduce baseline loading on Unit #5480 during FPC Treated test at notches 2, 4, & 6.

Figure 1

**CPR/StL&H RAILWAY
FUEL EFFICIENCY GAIN WITH FPC CATALYST**

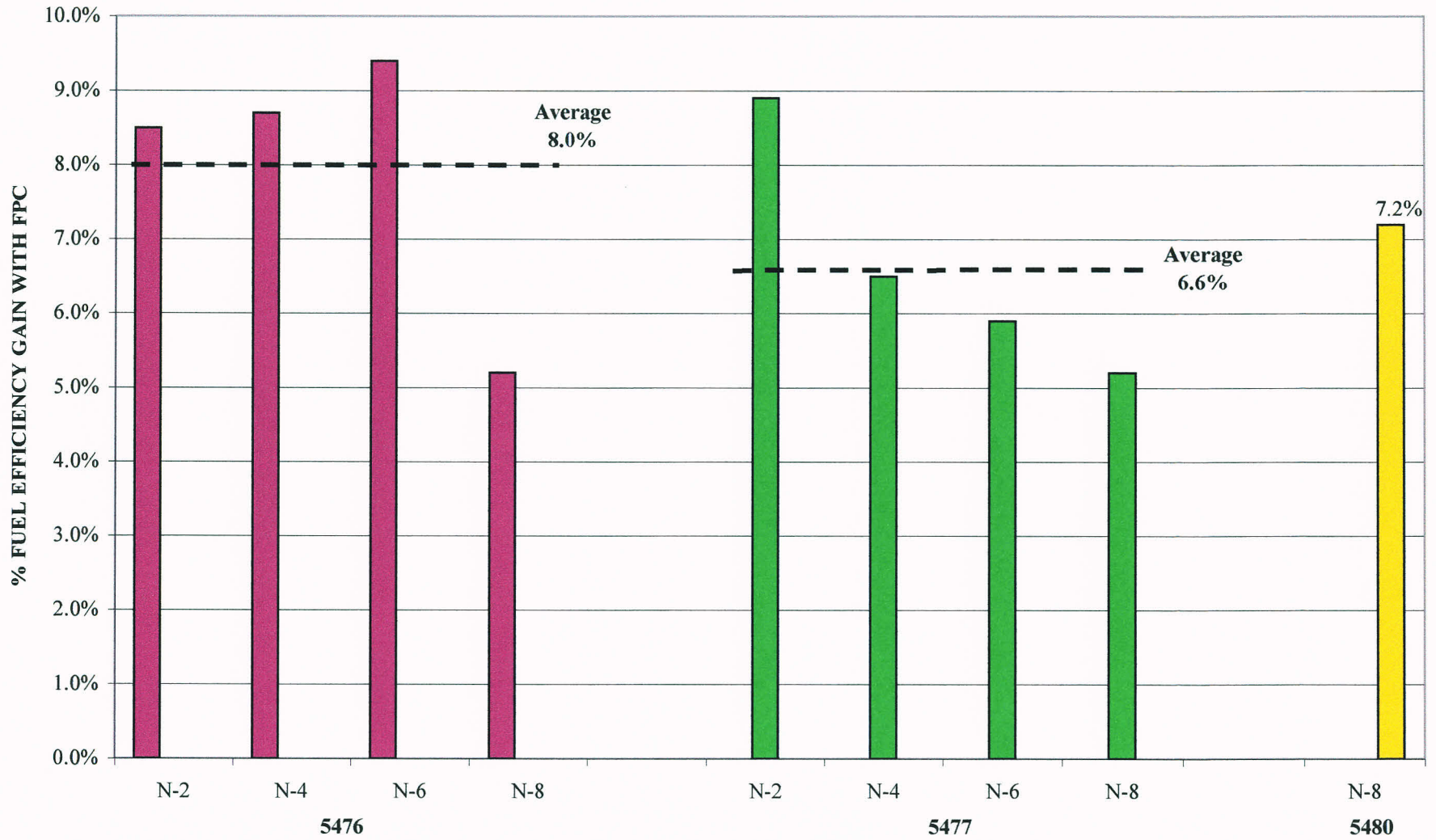


Table IV

**Canadian Pacific Railway
Eastern Network
St. Lawrence & Hudson Railway**

**Emissions Reduction with FPC™
Carbon Monoxide and Unburned Hydrocarbons**

Unit #	Notch	Baseline CO	Treated CO	% Change CO	Baseline HC	Treated HC	% Change HC
5476	2	0.014	0.010	-28.6%	4.0	3.0	-25.0%
	4	0.020	0.010	-50.0%	4.6	2.0	-56.5%
	6	0.093	0.040	-57.0%	5.0	3.2	-36.0%
	8	0.060	0.034	-43.3%	8.2	4.2	-48.8%
	Ave.			-44.7%			-41.6%
5477	2	0.013	0.010	-23.1%	5.0	3.8	-24.0%
	4	0.010	0.010	0.0%	4.0	3.0	-25.0%
	6	0.048	0.030	-37.5%	4.4	3.4	-22.7%
	8	0.030	0.020	-33.3%	4.8	3.4	-29.2%
	Ave.			-23.5%			-25.2%
5480	2	0.010	N/A		1.7	N/A	
	4	0.010	N/A		2.2	N/A	
	6	0.050	N/A		2.4	N/A	
	8	0.030	0.010	-66.7%	3.4	1.2	-64.7%

Figure 3

**CPR/StL&H RAILWAY
CARBON MONOXIDE LEVELS**

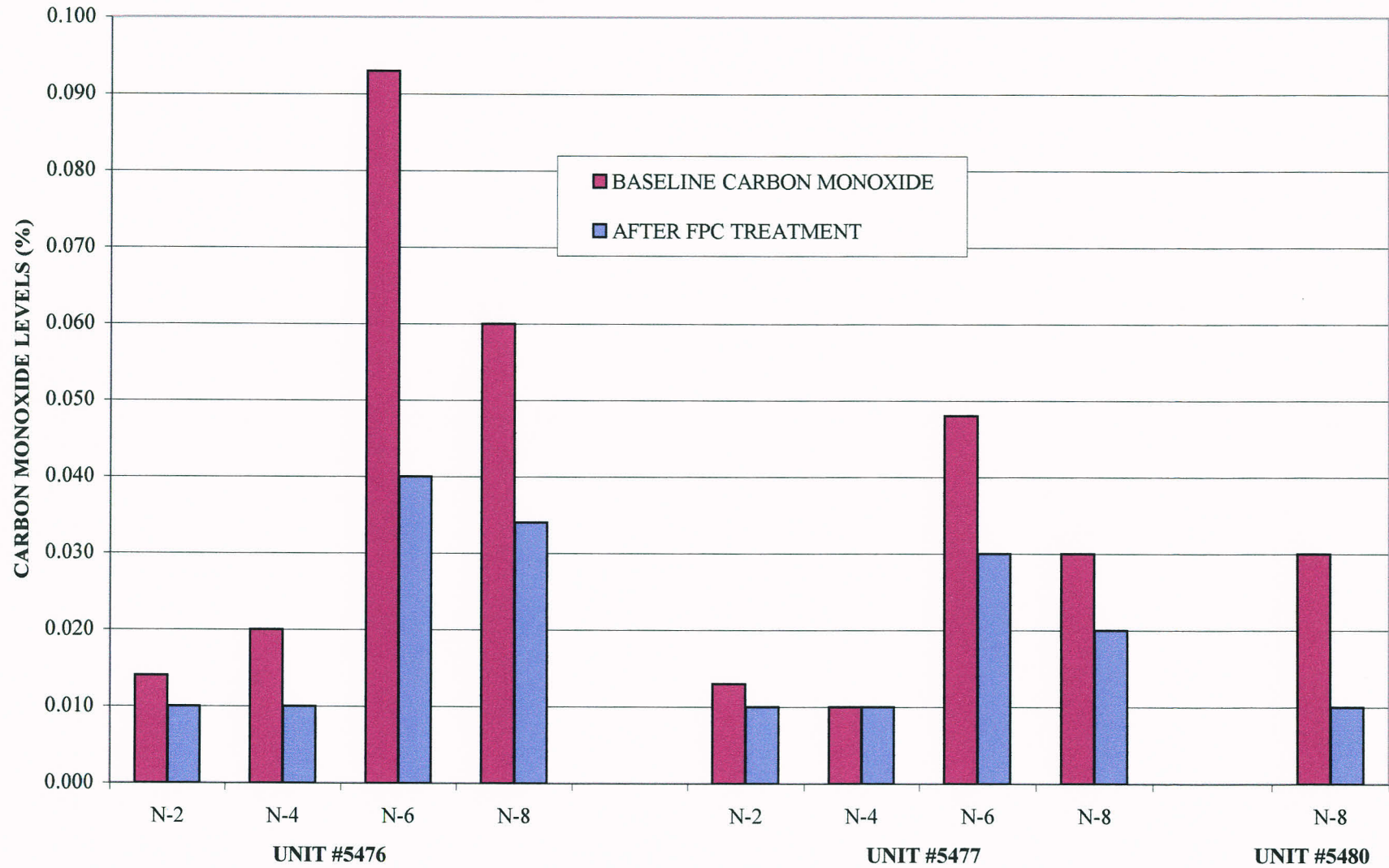


Figure 4

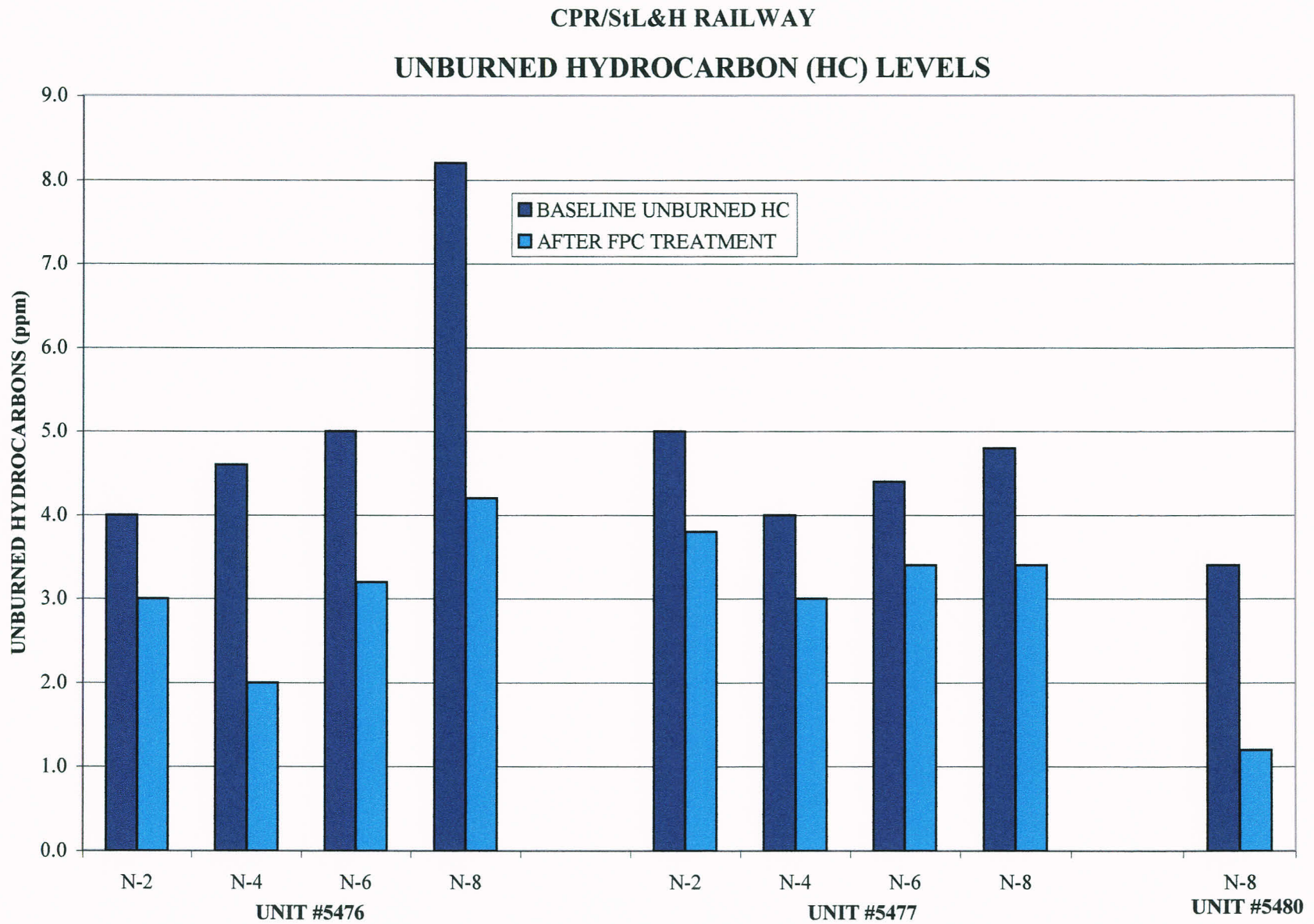


Table V

**Canadian Pacific Railway
Eastern Network
St. Lawrence & Hudson Railway**

**Smoke Reduction with FPC™
Based on Bacharach True-Spot Smoke Measurement**

<u>Unit No.</u>	<u>Notch</u>	<u>Baseline Smoke-Spot</u>	<u>FPC Treated Smoke-Spot</u>	<u>Percent Change</u>
5476	2	5.5	5.5	0.0%
5477	2	6.5	4.0	-38.5%
5480	2	4.0	N/A	N/A
Notch 2 Average				-19.2%
5476	4	7.0	6.5	-7.1%
5477	4	6.0	6.0	0.0%
5480	4	6.8	N/A	N/A
Notch 4 Average				-3.6%
5476	6	9.0	8.0	-11.1%
5477	6	7.0	7.0	0.0%
5480	6	5.0	N/A	N/A
Notch 6 Average				-5.6%
5476	8	8.0	8.0	0.0%
5477	8	8.0	6.5	-18.8%
5480	8	8.0	5.5	-31.3%
Notch 8 Average				-16.7%
Fleet Average				-11.3%

Note: Problems were experienced with collecting smokespots (on filter paper) during the "baseline" test" due to heavy rain during the middle of the testing.

Figure 5

**ALL RAILROADS LOAD BOX
SMOKE REDUCTION TESTS COMPARISON**

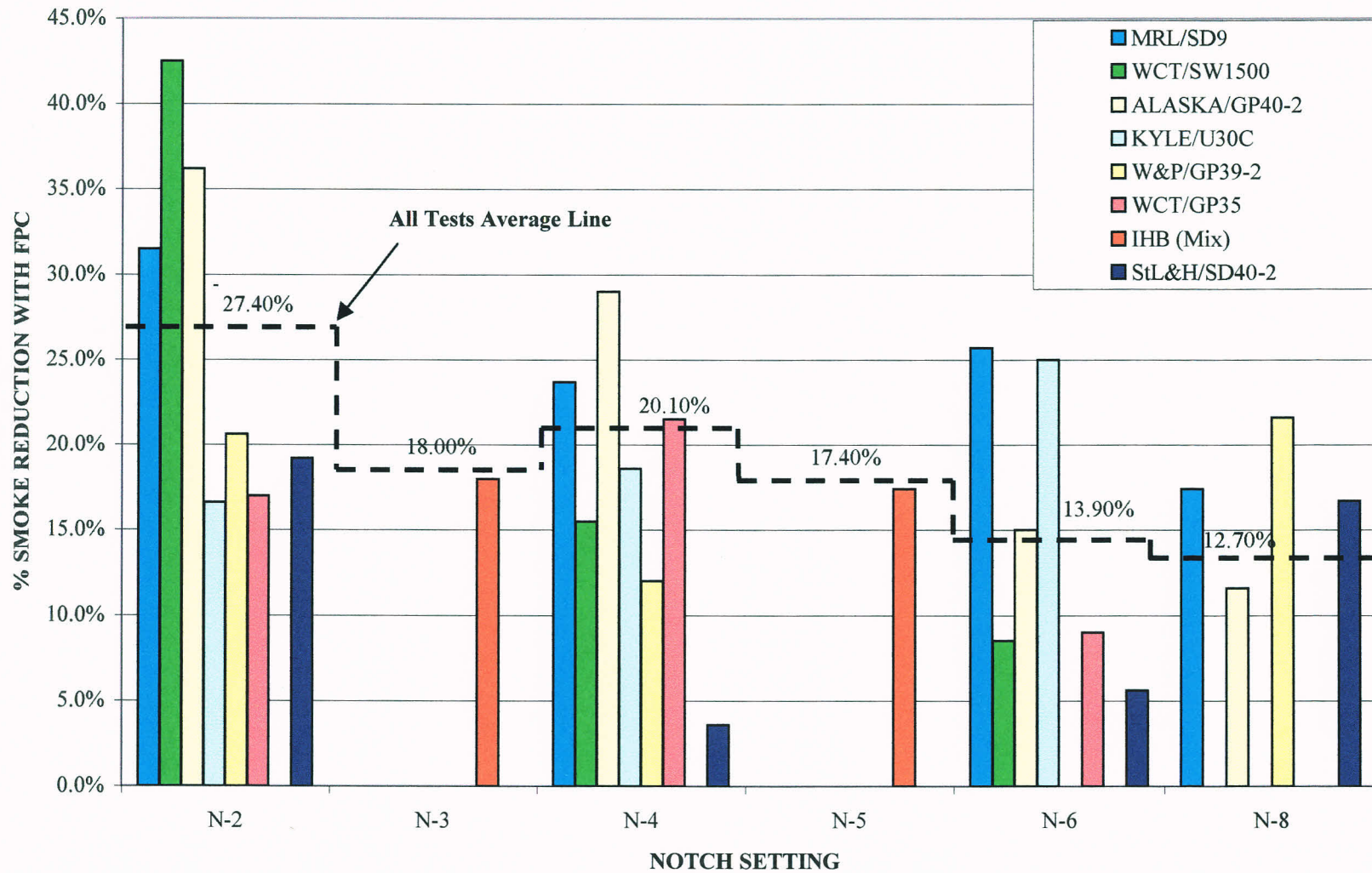


TABLE VI

CP Rail/StL&H
GREENHOUSE GAS REDUCTION CALCULATIONS

Emission Factors (g/l):

CO₂ = 2730CH₄ = 0.15N₂O = 1.1

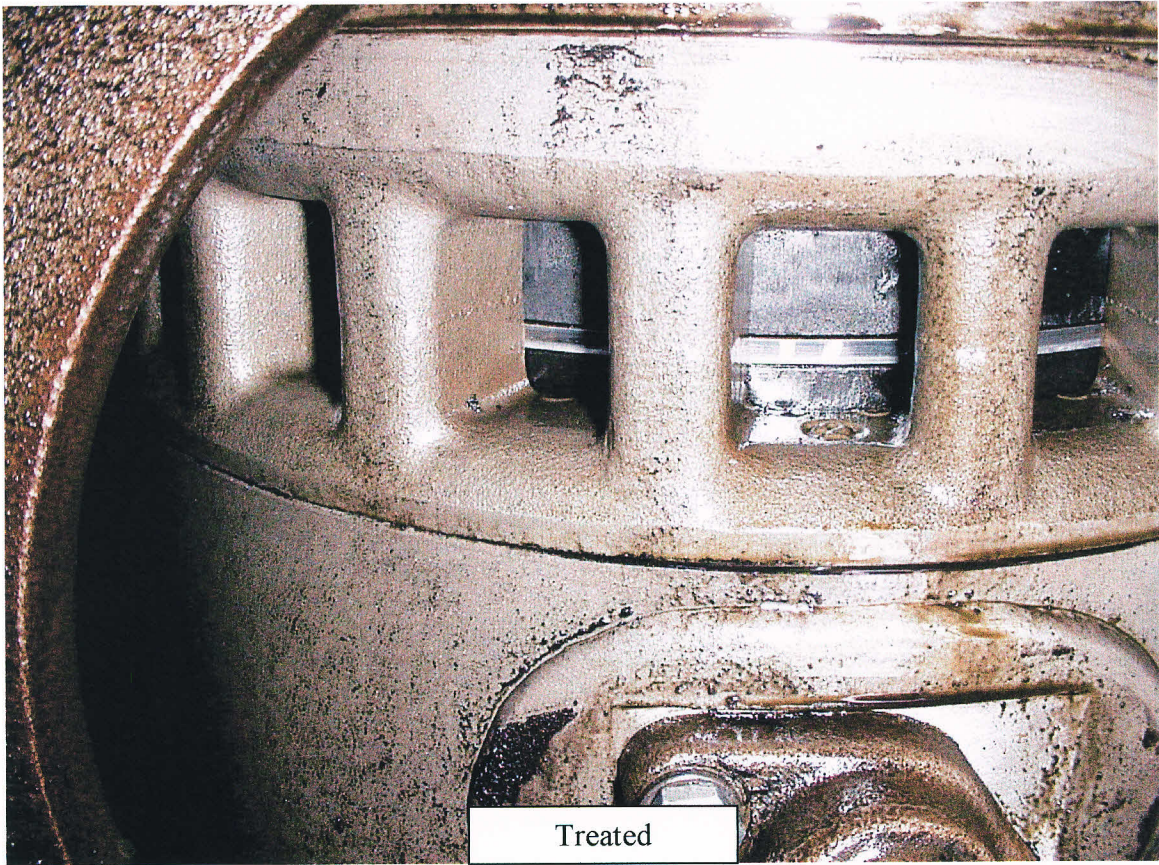
Fuel Type	"Untreated"	"FPC-2 Treatment"	
		5%	7%
% Reduction	0%	5%	7%
Fuel Usage (liters/yr)	750,000,000	712,500,000	697,500,000
Total CO ₂ (mt/yr)	2,047,500	1,945,125	1,904,175
CO₂ Reduction (mt/yr)	0	102,375	143,325
Total CH ₄ (mt/yr)	112.5	106.9	104.6
CH₄ Reduction (mt/yr)	0	5.6	7.9
Total N ₂ O (mt/yr)	825.0	783.2	767.2
N₂O Reduction (mt/yr)	0	41.8	57.8

**TOTAL GREENHOUSE
 GAS REDUCTION**
 (mt/yr)

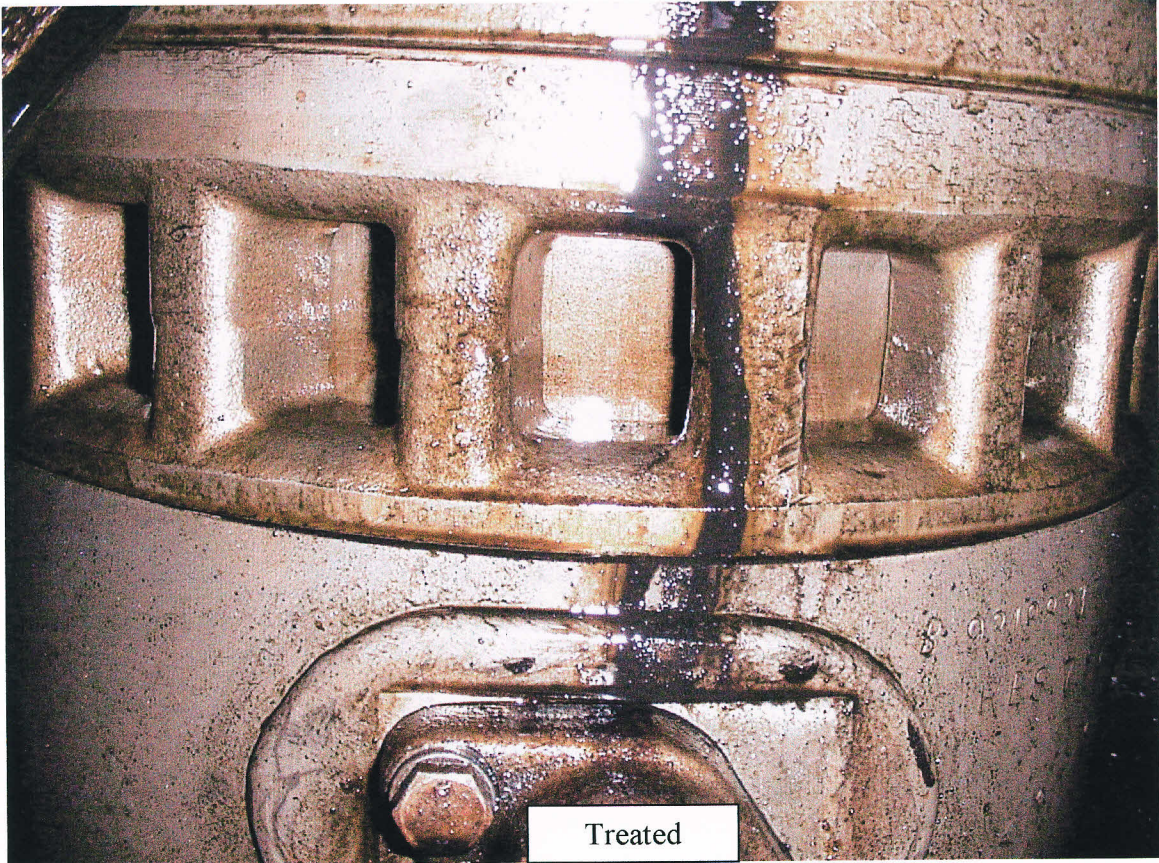
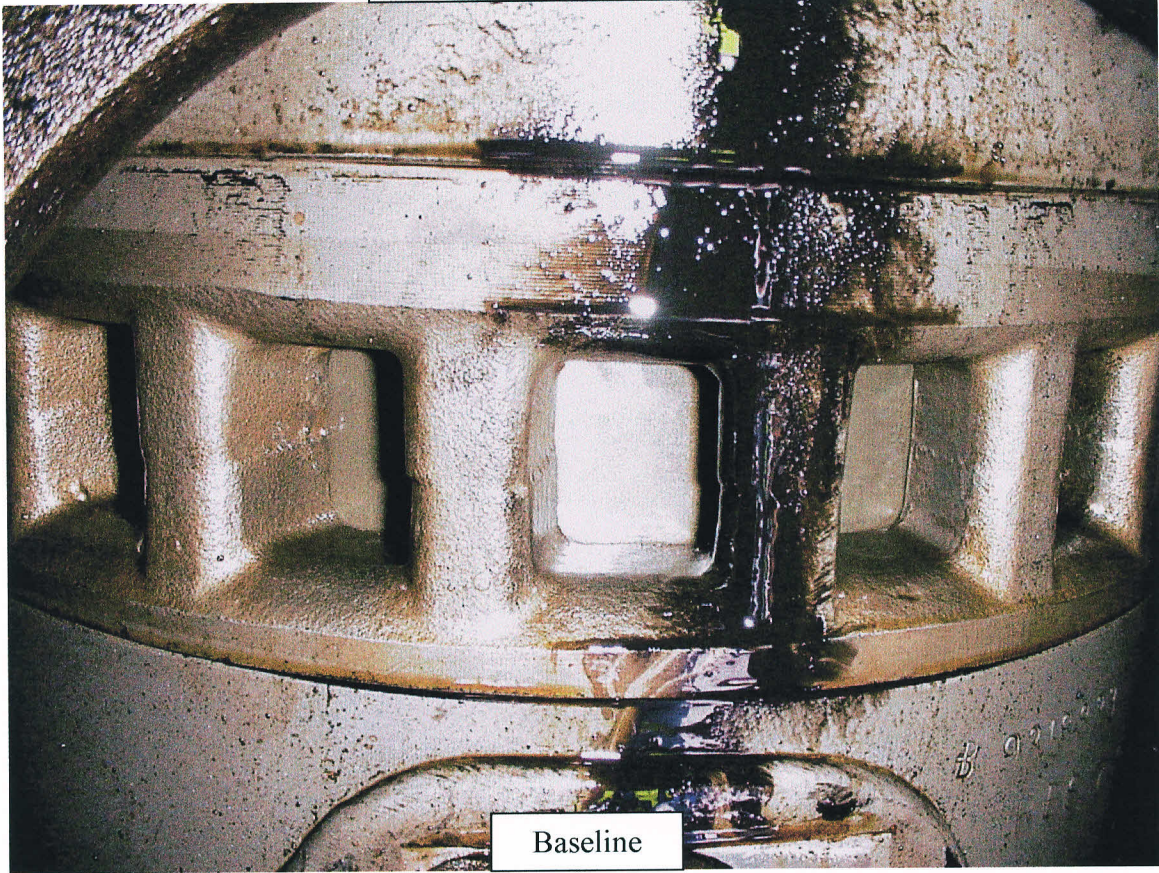
0

102,422143,391

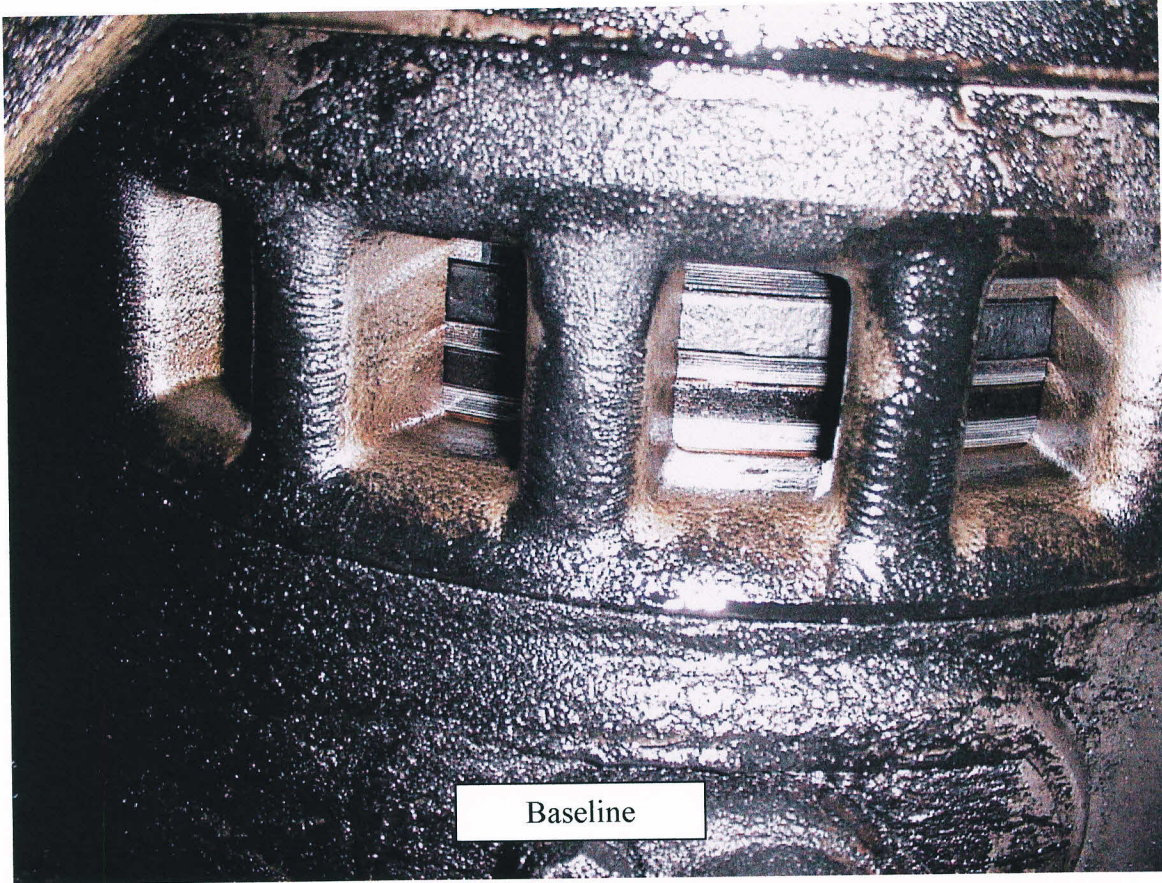
CPR/StL&H
Unit #1594 Cylinder #10



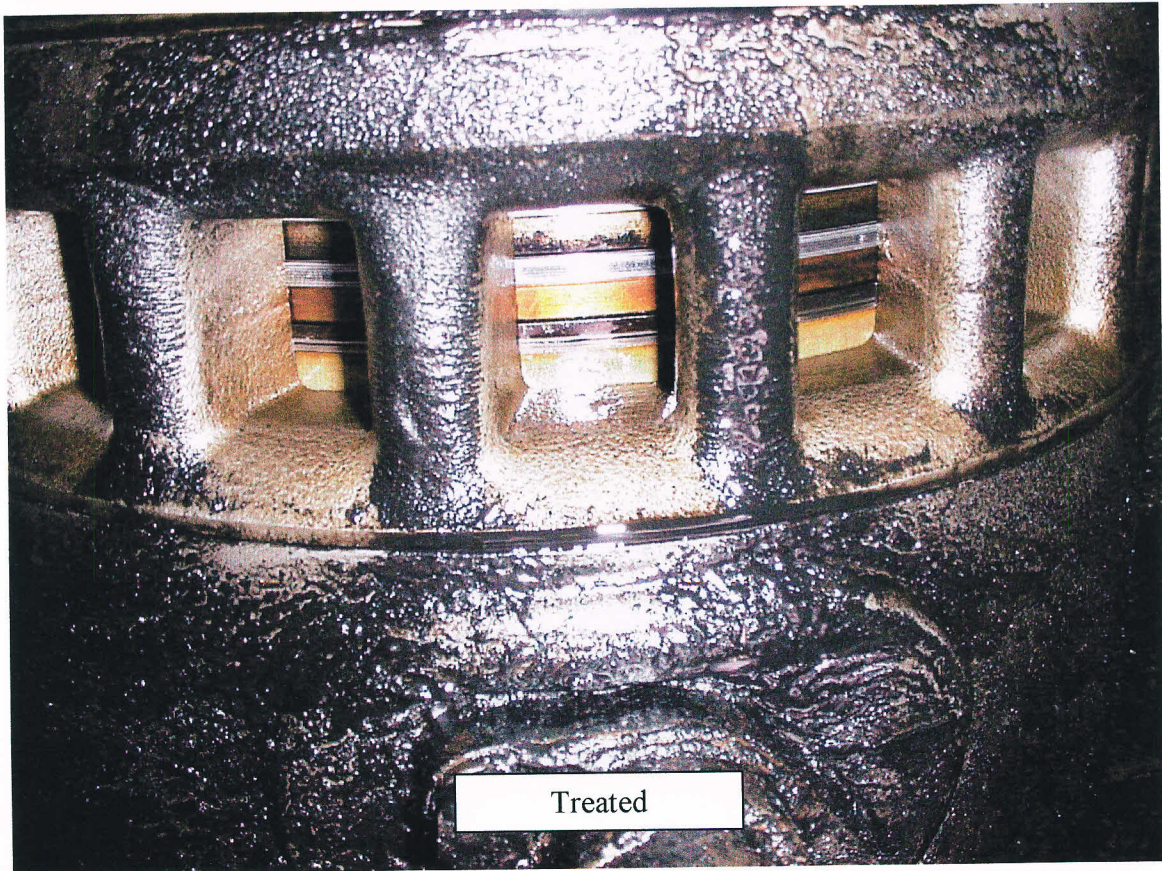
CPR/StL&H
Unit #1621 Cylinder #10



CPR/StL&H
Unit #5480 Cyl.#2



Baseline



Treated