Reducing Emissions & Fuel Consumption Enhancing Equipment Management

Mirenco Exhaust Gas Testing & Throttle Management



Marty Worth
Technology Specialist

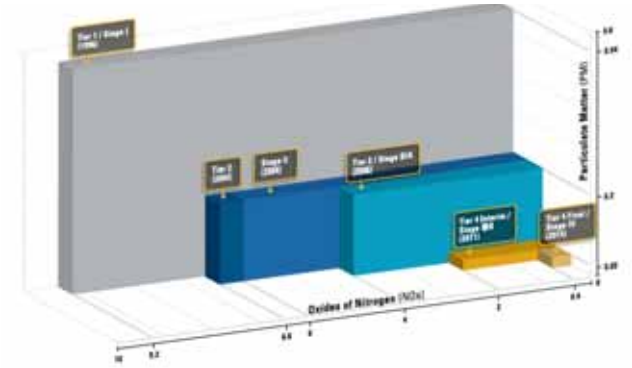
WHAYNE Technology Division

MIRENCO Emissions & Fuel Management System

5 Year History- Crude Oil Prices

Diesel Emissions – Regulation Trends

"Green" is becoming more important.



Is Mirenco a Product or Service?

Exhaust Gas Analysis (MDEP)

- **Evaluates engine combustion efficiency**
- **Report recommends possible repairs**
- **Repairs help to reduce fuel & emissions**

Throttle Management Controller (C-Max/D-Max)

- **Black box between throttle pedal and fuel computer.**
- **Regulates throttle application on acceleration and WOT to reduce "over-fueling".**

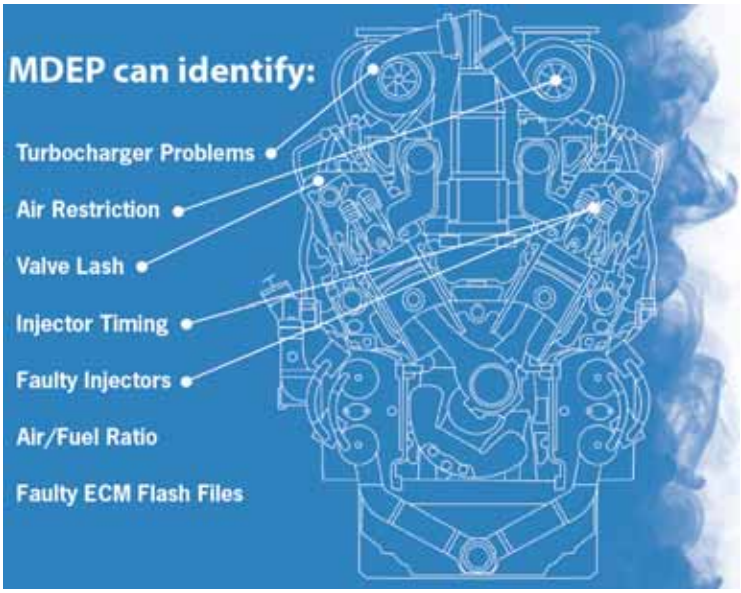
MDEP Fuel Reduction Strategy

1. Test all significant fuel consuming machines on site.
2. Use DPM data to identify machines wasting fuel.
3. Review Mirenco report to identify potential repairs that can improve fuel efficiency.
4. Create repair plan for each machine that is wasting fuel.
5. Hours remaining till engine rebuild can affect repair plan.
6. Objective is to balance "Cost of Repairs" & "Fuel Cost Savings".

Exhaust Gas Test Applications

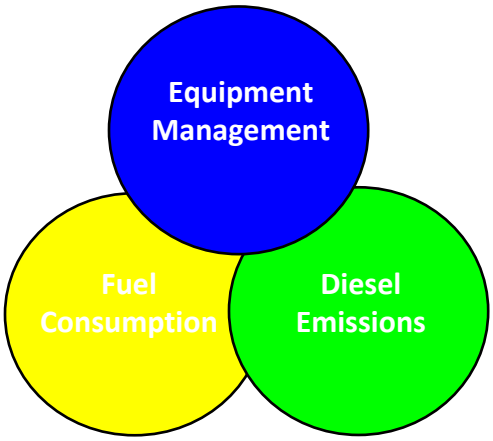
- ***Underground Mining – Quarries, Metal, etc.***
- ***Emissions Sensitive Jobs – Federal Sites***
- ***Surface Mining – Coal, Gold, Quarries***
- ***Heavy Construction Sites***
- ***On Highway Trucks***
- ***Machine Rebuilds***
- ***Engine Rebuild Centers***
- ***Stationary Engines***
- ***Marine***

Typical Combustion Related Issues that contribute to DPM Density:



You Cannot Manage What You Cannot Measure

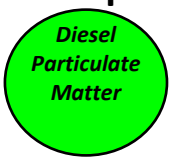
Exhaust Gas Testing focuses on improving 3 critical areas.



A Diagnostic Tool … like Scheduled Oil Sampling!

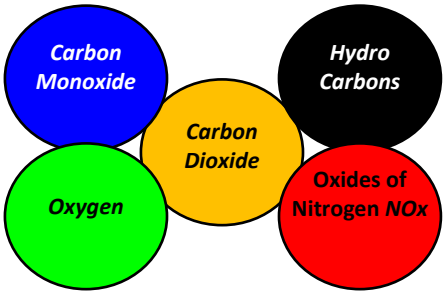
A MDEP is comprised of two separate tests

DPM Snap Test

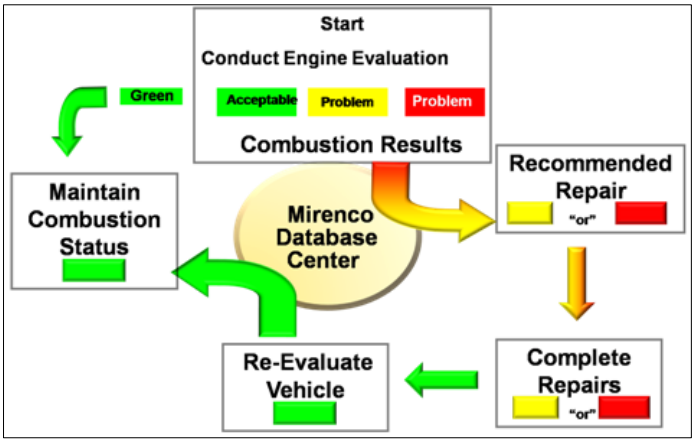


High DPMs=
Over fueling=
Black Smoke=
High Emissions=
Wasted Fuel

5 Gas analysis

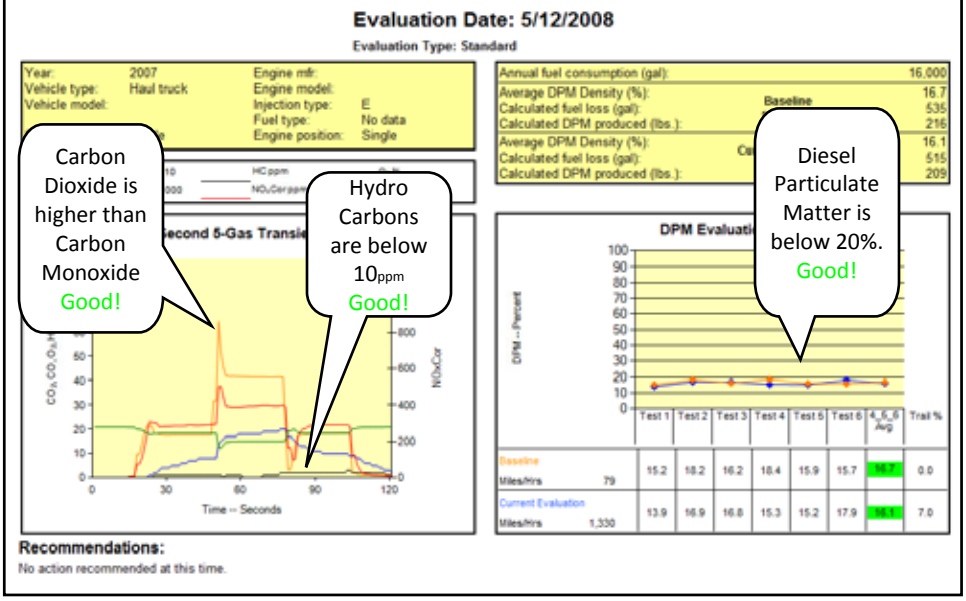


Exhaust Gas Analysis (MDEP)- Condition Monitoring

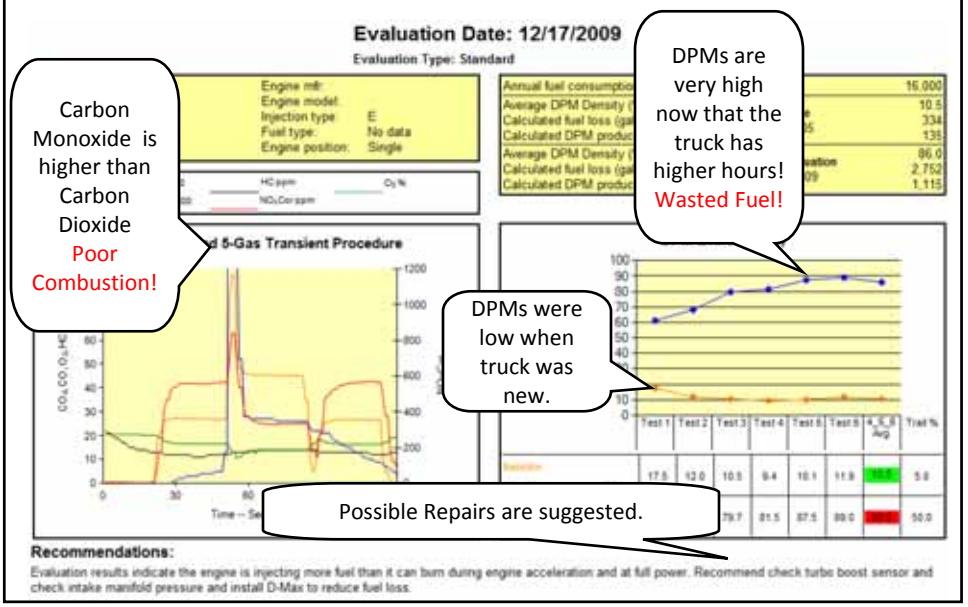


Exhaust Gas Test Results

Haul Truck– Emissions look Good!



Exhaust Gas Test Results
Haul Truck– Emissions Very Poor!

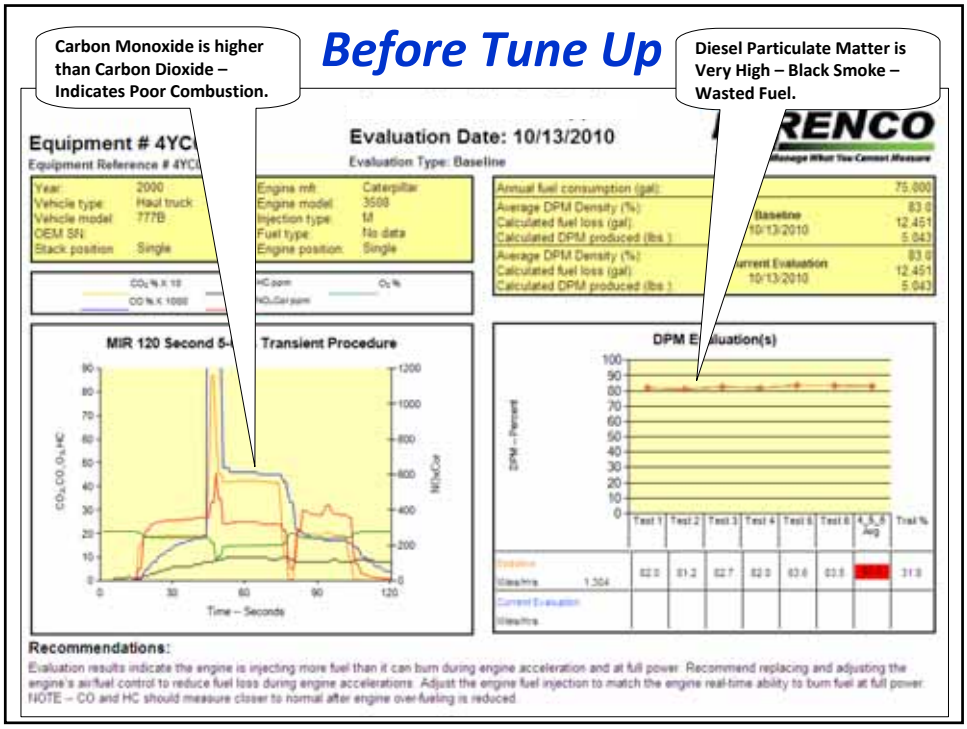


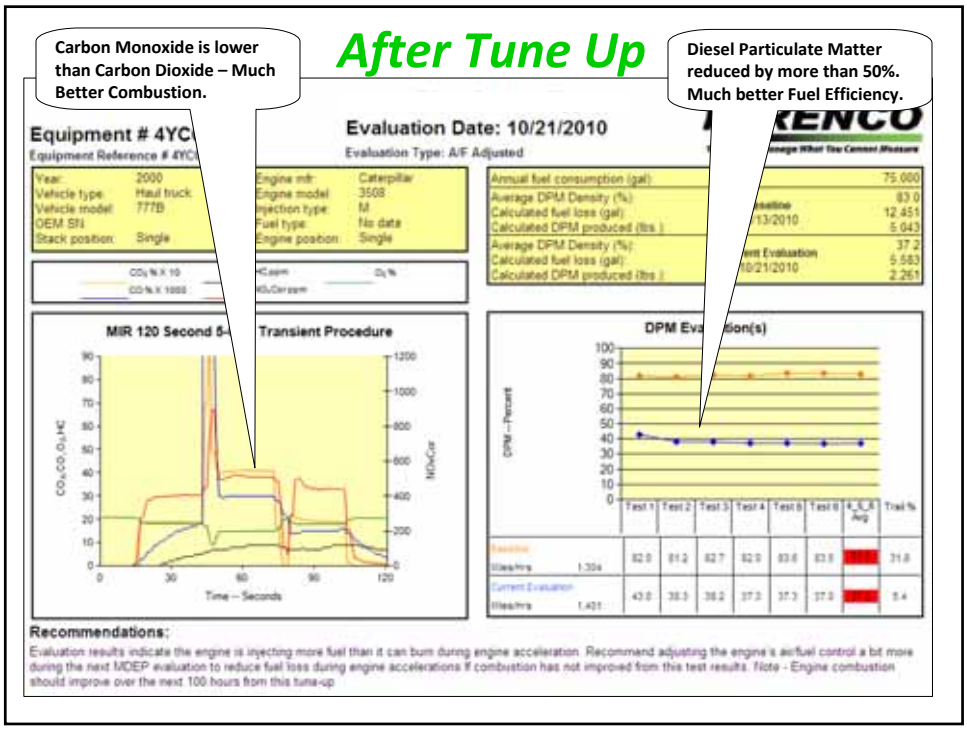
Cat 777B in Surface Coal

Use of MDEP Exhaust Gas Testing to Improve

*Fuel Efficiency

*Engine Life


Before Tune Up
Carbon Monoxide is higher than Carbon Dioxide – Indicates Poor Combustion.
Diesel Particulate Matter is Very High – Black Smoke – Wasted Fuel.
Equipment # 4YC
Evaluation Date: 10/13/2010
Evaluation Type: Baseline
Year: 2000
Vehicle type: Haul truck
Vehicle model: 777B
OEM SN:
Stack position: Single
Engine mfr: Caterpillar
Engine model: 3508
Injection type: M
Fuel type: No data
Engine position: Single
Annual fuel consumption (gal): 75,000
Average DPM Density (%): 83.0
Calculated fuel loss (gal): 12,451
Calculated DPM produced (lbs.): 5,043
Baseline 10/13/2010
Current Evaluation 10/13/2010
MIR 120 Second 5- Transient Procedure
Time – Seconds
DPM E uation(s)
DPM – Percent
Recommendations:
Evaluation results indicate the engine is injecting more fuel than it can burn during engine acceleration and at full power. Recommend replacing and adjusting the engine's air/fuel control to reduce fuel loss during engine accelerations. Adjust the engine fuel injection to match the engine real-time ability to burn fuel at full power. NOTE – CO and HC should measure closer to normal after engine over-fueling is reduced.


After Tune Up
Carbon Monoxide is lower than Carbon Dioxide – Much Better Combustion.
Diesel Particulate Matter reduced by more than 50%. Much better Fuel Efficiency.
Equipment # 4YC
Evaluation Date: 10/21/2010
Evaluation Type: A/F Adjusted
Year: 2000
Vehicle type: Haul truck
Vehicle model: 777B
OEM SN:
Stack position: Single
Engine mfr: Caterpillar
Engine model: 3508
Injection type: M
Fuel type: No data
Engine position: Single
Annual fuel consumption (gal): 75,000
Average DPM Density (%): 83.0
Calculated fuel loss (gal): 12,451
Calculated DPM produced (lbs.): 5,043
Baseline 13/2010
Current Evaluation 10/21/2010
Average DPM Density (%): 37.2
Calculated fuel loss (gal): 5,583
Calculated DPM produced (lbs.): 2,261
MIR 120 Second 5- Transient Procedure
Time – Seconds
DPM Eva ion(s)
DPM – Percent
Recommendations:
Evaluation results indicate the engine is injecting more fuel than it can burn during engine acceleration. Recommend adjusting the engine's air/fuel control a bit more during the next MDEP evaluation to reduce fuel loss during engine accelerations. If combustion has not improved from this test results. Note - Engine combustion should improve over the next 100 hours from this tune-up.

	GALLONS	EST.COST / GAL	TOTAL $ WASTED FUEL
BASLINE CALCULATED FUEL LOSS (gal)	12,451	$3.50	$ 43,579
CURRENT CALCULATED FUEL LOSS (gal)	5,583	$3.50	$ 19,541
TOTAL SAVED AFTER TUNE-UP PER YEAR	**6,868**		**$ 24,038**
	TOTAL SAVED / MONTH		**$ 2,003**
TUNE-UP W/ INJECTOR REPLACEMENT			$ 7,500
TUNE-UP W/ INJECTOR REPLACEMENT PAYBACK			**3.74 months**
MONEY SAVED 1ST YEAR AFTER TUNE-UP COSTS			**$ 16,538**

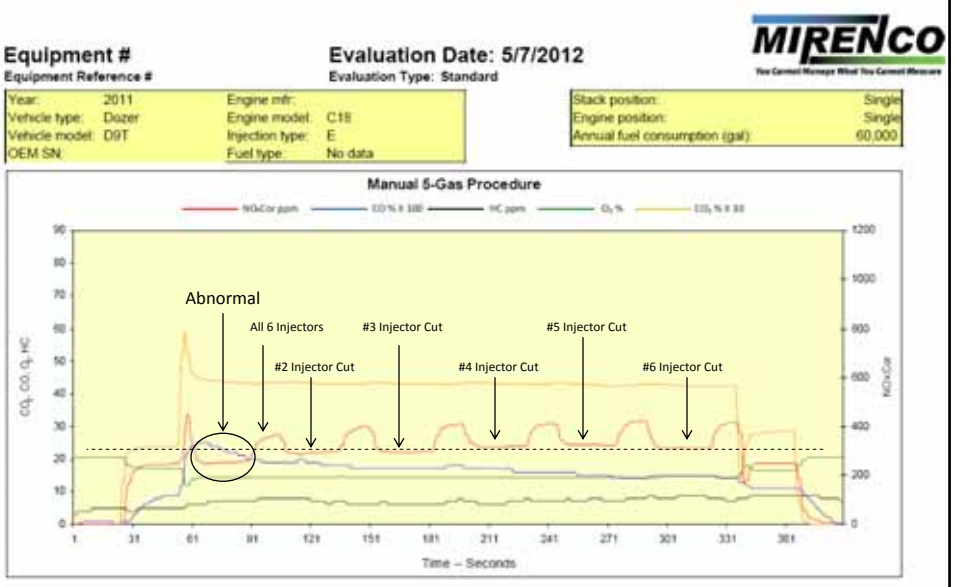
777B Oil Sample Benefits

Note decrease in Iron and Soot

After Tune Up

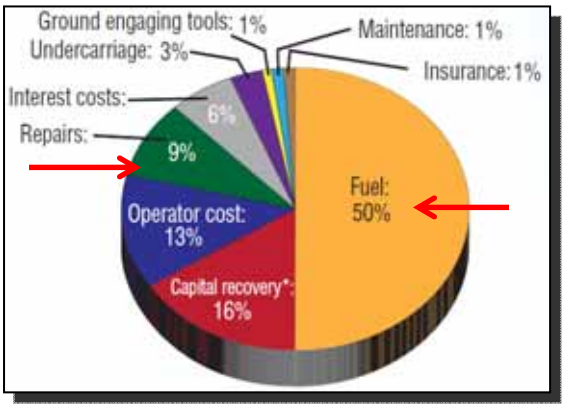
Component	Sample Dte	Oil Hrs	Filter Change	Al	Si	Fe	Soot
ENGINE	1-Jun-10		Yes	1	3	46	209
ENGINE	29-Jun-10	302	Yes	1	2	38	204
ENGINE	5-Aug-10	337	Yes	1	3	42	230
ENGINE	28-Sep-10	313	Yes	1	3	24	124
TUNE -UP							
ENGINE	22-Nov-10	351	Yes	1	3	21	36
ENGINE	3-Jan-11	328	Yes	2	2	19	24

Injector Cut-Out Results, Single Stack



Cost Benefit

Cat D11T
Hourly Cost Estimate= $261.19
5000 hours/year



Recommended test interval: 3-6 months

Test Price: $375

$.15-$.30/hr!

C-Max and D-Max

Throttle Application Management

C-Max Applications

- *Target 400 HP and above.*
- *High Duty Cycle – Heavily Loaded*
- *Underground Mining – Quarries, Metal, etc.*
- *Emissions Sensitive Jobs – Federal Sites*
- *Surface Mining – Coal, Gold, Quarries*
- *Heavy Construction Sites*
- *On Highway Trucks*
- *Machine Rebuilds*
- *Marine*

C-Max / D-Max®

Device helps to move the "Style of Throttle Application" from the Machine Operator to the Equipment Manager.

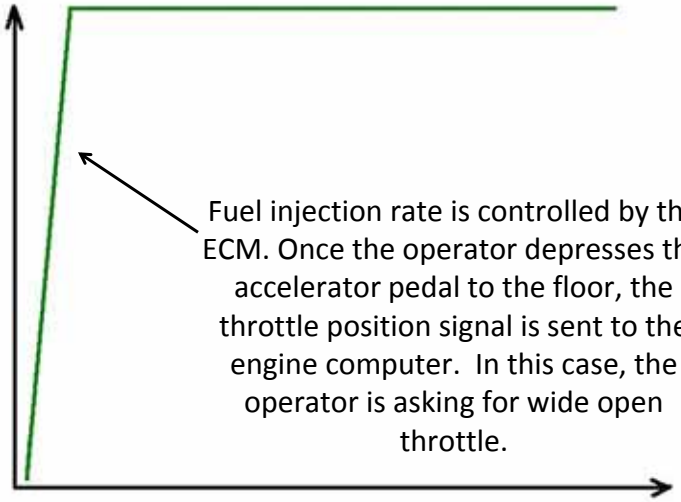
C-Max & D-Max can turn a "Spirited" operator into a "Conservative" operator with no loss of power or productivity!

C-Max or D-Max

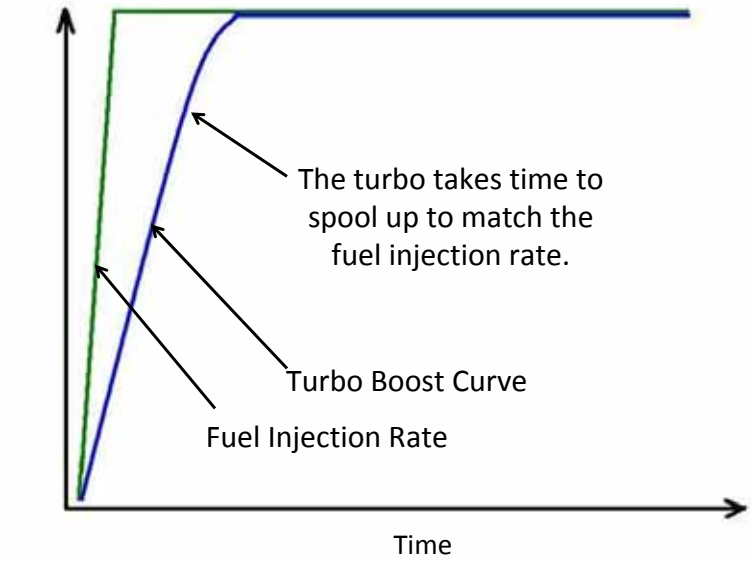
Method 1.

Control Fuel Injection during machine acceleration.

Fuel Injection vs. Time



Fuel Injection & Turbo Boost vs. Time



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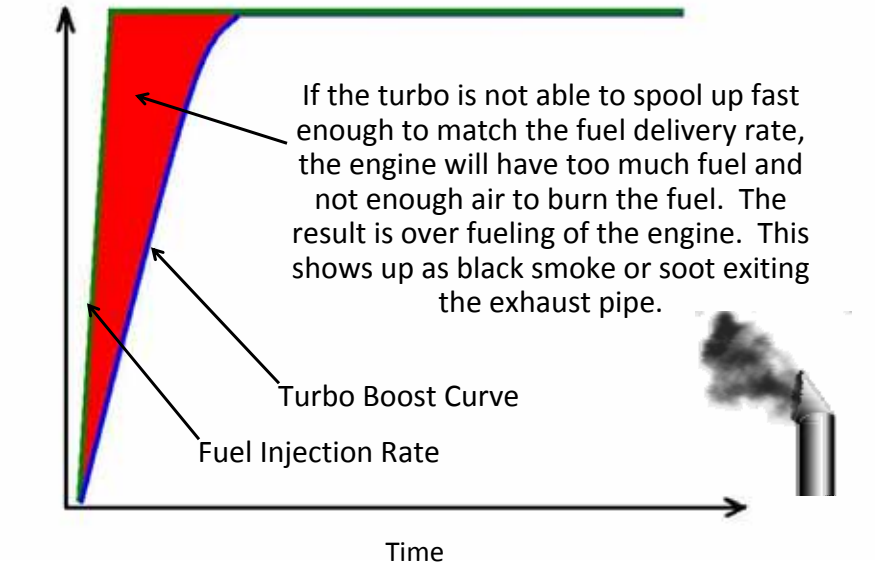

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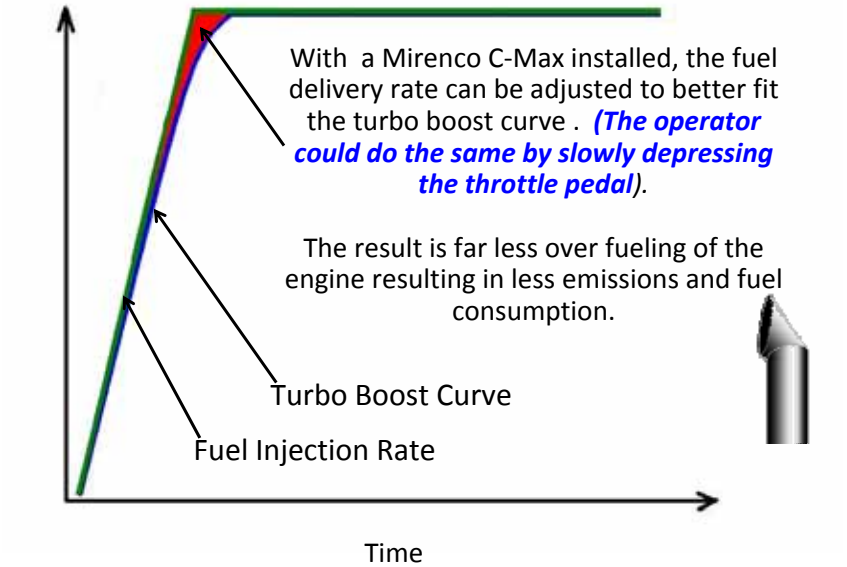
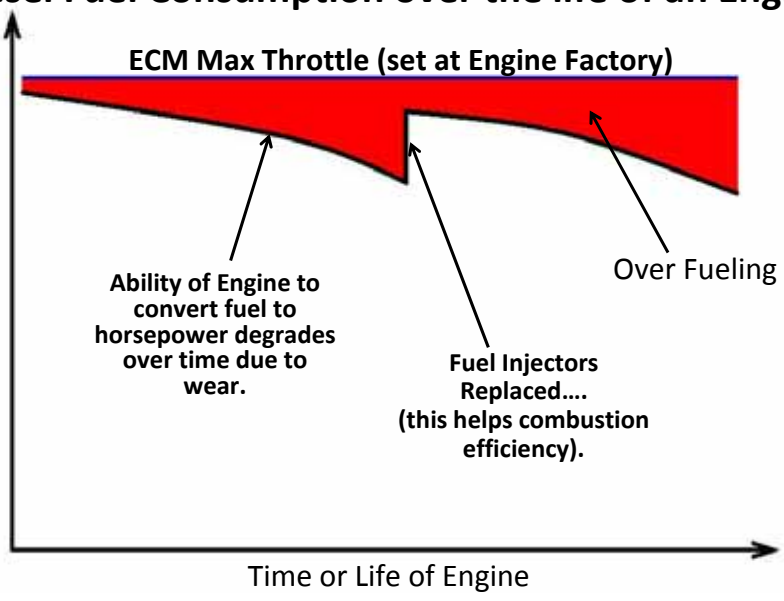


C-Max or D-Max

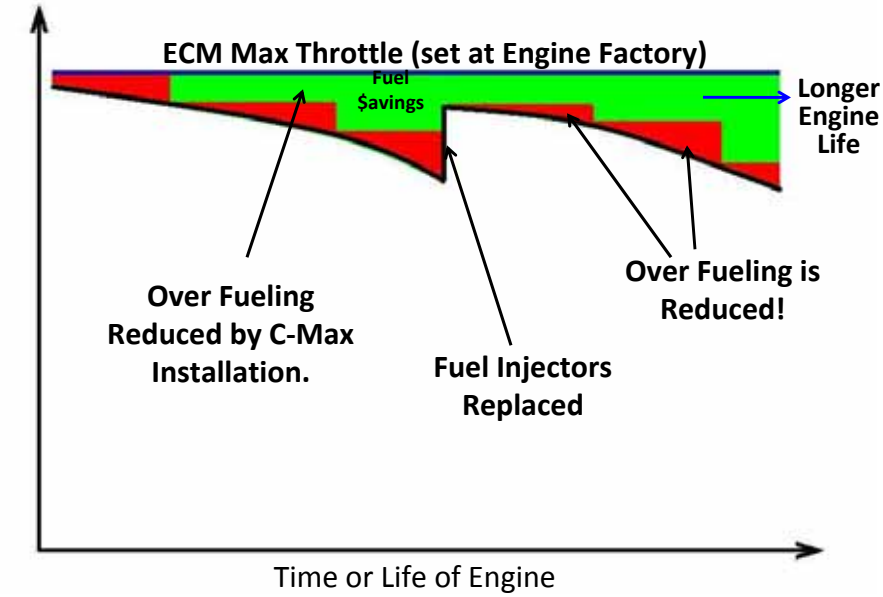
Method 2.

Control Fuel Injection
at wide open throttle
"Pedal to the Metal"

Diesel Fuel Consumption over the life of an Engine.



Diesel Fuel Consumption over the life of an Engine.



WHAYNE Technology Division

MIRENCO Emissions & Fuel Management System

Field Test of Throttle Management

Heavy Hauler – Fuel Tanker & C-Max

- Very Consistent Haul
- Knoxville to London
- Gas & Fuel transportation
- 2 to 3 hauls per day
- Max Throttle Applications
- Jellico Mountain
- Before C-Max = 5.62 mpg
- After C-Max = 6.04 mpg
- Improvement of **7.4%**

C-Max D9R Dozer Study

MIRENCO
Emissions & Fuel Management System

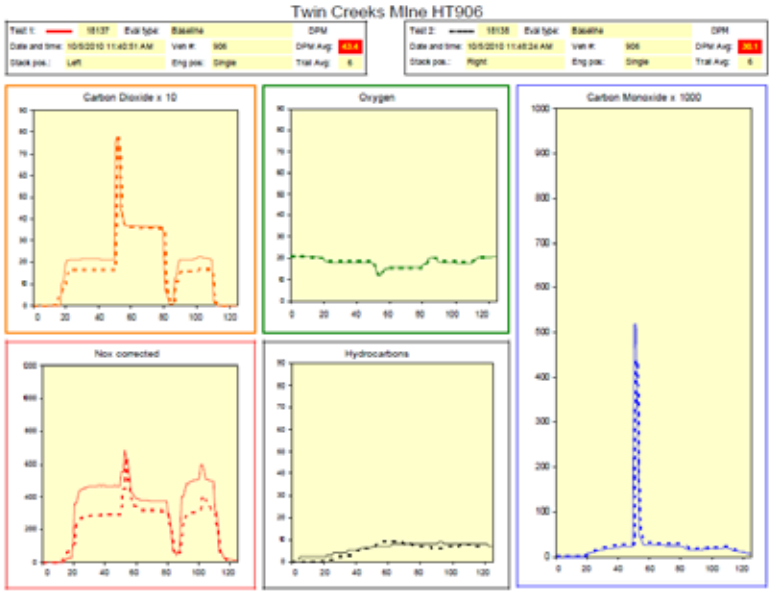
	"On"	*"Off"*
• *Blade Volume per pass - BCY*	*7.01*	*7.22*
• *Tractor Cycles per hour*	*59.6*	*57.4*
• *Production – Yard per hour*	*421*	*411*
• *Fuel Consumption - Gal per hour*	*17.03*	*18.44*
• *Fuel Efficiency - BCY per gallon*	*24.75*	*22.28*
• *Fuel Efficiency Advantage*	*11 %*	←

Cat D11R C-Max Study

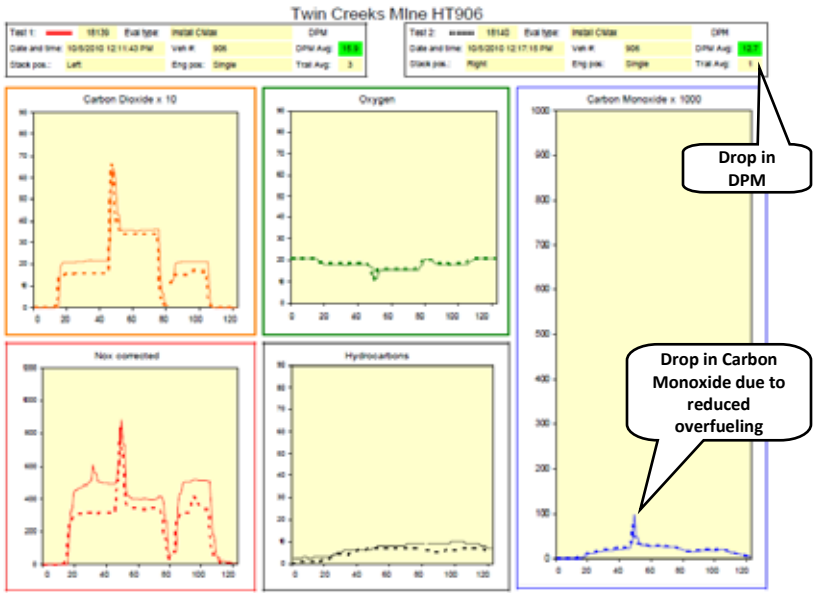
Eastern KY Land Development Mine

Mirenco Fuel Evaluation						
Customer: Mayo	Cat D11R	7PZ00410				
Location: Martin County						
		Baseline Data			C-Max Data	
Application	Life to Date	Data taken to establish Baseline + Date of C-Max Install	Baseline Test Period		Data taken after runing Cmax	C-Max Test Period
C-Max On or Off?	Off	Off	Off		On	On
Date	2/10/2011	2/25/2011			4/8/2011	
Cummulative Hours Total	5,121	5,324	203		5,857	533
Cummulative Gallons Total	136,650	142,050	5,400		155,262	13,212
Cummulative Gallons per Hour	**26.68**		**26.60**			**24.79**
Change in GPH						1.81
% Improvement						**6.8%**
Hours per Year						6000
Total Fuel savings per year gallons						10,878
Fuel Cost per Gallon						$ 3.25
Savings per Year						**$ 35,353**

Nevada Cat 793C Before C-Max



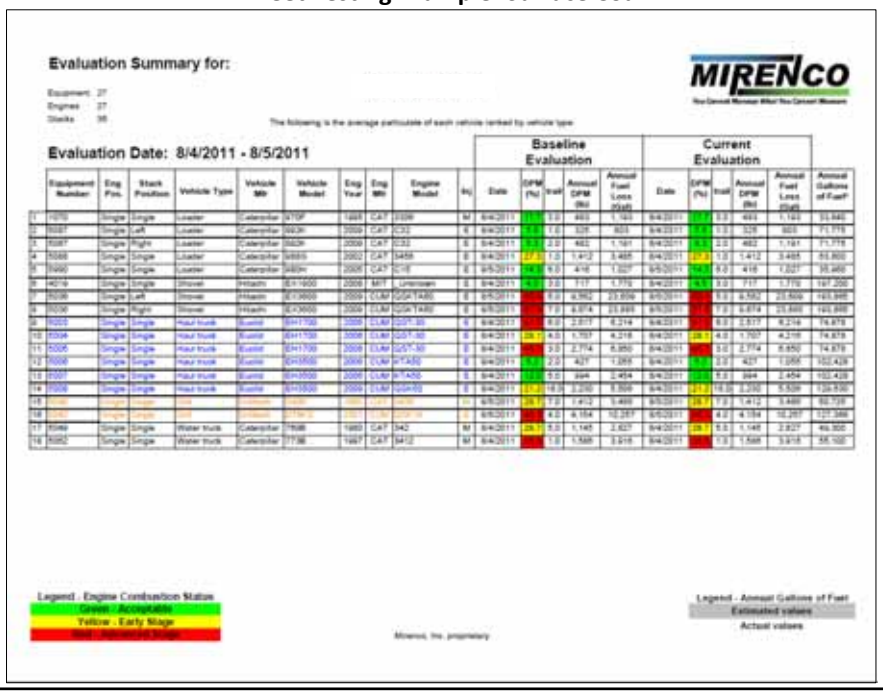
Nevada Cat 793C *After* C-Max



Payback Analysis

Fuel Savings from Improved Throttle Management			
Machine	**D11R**	**785C**	**992H**
Hourly Fuel Consumption	32	30	31
Hours worked per year	5000	5000	5000
Price of Fuel	$ 3.20	$ 3.20	$ 3.20
Annual Fuel Cost	$ 512,000	$ 480,000	$ 496,000
Estimated Fuel Savings	6%	2%	3%
$ Savings per Year	$ 30,720	$ 9,600	$ 14,880
$ Savings per Month	$ 2,560	$ 800	$ 1,240
Cost of Service	$ 2,325	$ 2,325	$ 2,325
Payback in Months	0.9	2.9	1.9

Fleet Testing Example- Surface Coal



Evaluation Summary for:

MIRENCO

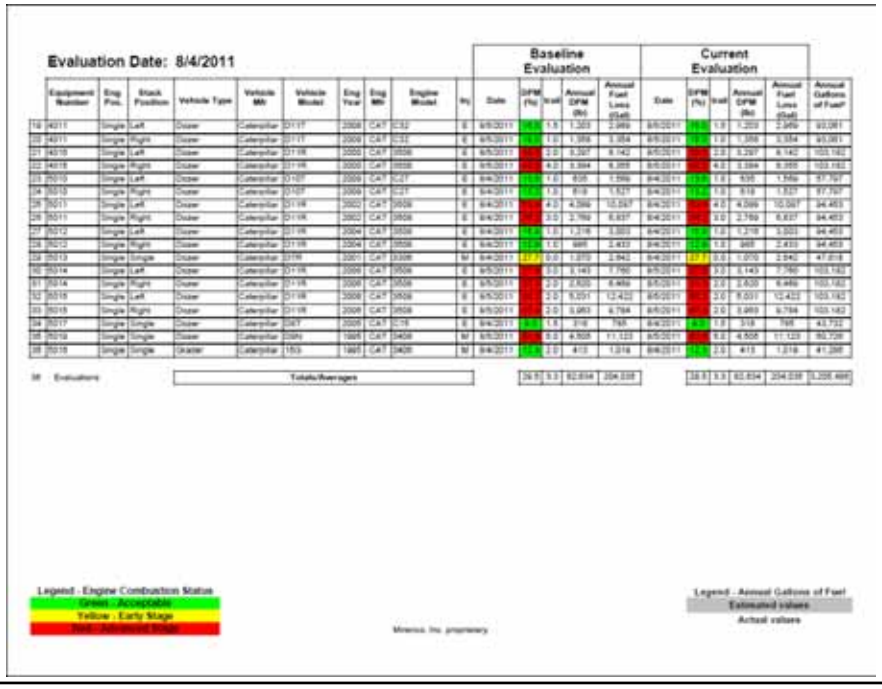
Evaluation Date: 8/4/2011 - 8/5/2011

	Equipment Number	Eng Pos.	Stack Position	Vehicle Type	Vehicle Mfr	Vehicle Model	Eng Year	Eng Mfr	Engine Model	Hrs	Baseline Evaluation Date	Baseline DPM (%)	Baseline Instl	Baseline Annual DPM (lb)	Baseline Annual Fuel Loss (Gal)	Current Evaluation Date	Current DPM (%)	Current Instl	Current Annual DPM (lb)	Current Annual Fuel Loss (Gal)	Annual Gallons of Fuel*
1	1070	Single	Single	Loader	Caterpillar	470F	1995	CAT	3306	M	8/4/2011	11.1	5.0	463	1,783	8/4/2011	11.1	5.0	463	1,783	33,940
2	5087	Single	Left	Loader	Caterpillar	992K	2009	CAT	C32	E	8/4/2011	7.4	1.0	328	803	8/4/2011	7.4	1.0	328	803	71,779
3	5087	Single	Right	Loader	Caterpillar	992K	2009	CAT	C32	E	8/4/2011	8.3	2.0	462	1,191	8/4/2011	8.3	2.0	462	1,191	71,779
4	5088	Single	Single	Loader	Caterpillar	980G	2002	CAT	3456	E	8/4/2011	17.1	1.0	1,412	3,465	8/4/2011	17.1	1.0	1,412	3,465	83,800
5	5990	Single	Single	Loader	Caterpillar	980H	2005	CAT	C18	E	8/5/2011	14.3	8.0	416	1,027	8/5/2011	14.3	8.0	416	1,027	35,460
6	4019	Single	Single	Shovel	Hitachi	EX1900	2006	MIT	Unknown	E	8/4/2011	4.3	3.0	717	1,770	8/4/2011	4.3	3.0	717	1,770	197,200
7	5036	Single	Left	Shovel	Hitachi	EX3600	2009	CUM	QSK78A60	E	8/5/2011		8.0	8,582	23,609	8/5/2011		8.0	8,582	23,609	163,995
8	5036	Single	Right	Shovel	Hitachi	EX3600	2009	CUM	QSK78A60	E	8/5/2011		7.0	8,874	23,865	8/5/2011		7.0	8,874	23,865	163,995
9	5003	Single	Single	Haul truck	Euclid	EH1700	2008	CUM	QSX15-60	E	8/4/2011		8.0	2,877	8,214	8/4/2011		8.0	2,877	8,214	74,878
10	5004	Single	Single	Haul truck	Euclid	EH1700	2008	CUM	QSX15-60	E	8/4/2011	28.1	4.0	1,707	4,218	8/4/2011	28.1	4.0	1,707	4,218	74,878
11	5005	Single	Single	Haul truck	Euclid	EH1700	2008	CUM	QSX15-60	E	8/4/2011		3.0	2,774	6,850	8/4/2011		3.0	2,774	6,850	74,878
12	5000	Single	Single	Haul truck	Euclid	EH3500	2008	CUM	QSK78A60	E	8/4/2011	6.1	2.0	427	1,055	8/4/2011	6.1	2.0	427	1,055	102,429
13	5001	Single	Single	Haul truck	Euclid	EH3500	2008	CUM	QSK78A60	E	8/4/2011	2.2	5.0	994	2,454	8/4/2011	2.2	5.0	994	2,454	102,429
14	5009	Single	Single	Haul truck	Euclid	EH3500	2009	CUM	QSK60	E	8/4/2011	21.1	16.0	2,230	5,509	8/4/2011	21.1	16.0	2,230	5,509	124,530
15	5030	Single	Single	Drill	Caterpillar	MD6	1999	CAT	3406	M	8/5/2011	26.7	7.0	1,412	3,489	8/5/2011	26.7	7.0	1,412	3,489	50,728
16	5031	Single	Single	Drill	Caterpillar	MD6	1999	CAT	3406	M	8/5/2011		4.0	4,164	10,287	8/5/2011		4.0	4,164	10,287	127,386
17	5049	Single	Single	Water truck	Caterpillar	773B	1993	CAT	3412	M	8/4/2011	26.7	5.0	1,145	2,827	8/4/2011	26.7	5.0	1,145	2,827	46,800
18	5052	Single	Single	Water truck	Caterpillar	773E	1997	CAT	3412	M	8/4/2011		1.0	1,588	3,918	8/4/2011		1.0	1,588	3,918	55,102

Legend - Engine Combustion Status
Green - Acceptable
Yellow - Early Stage
Red - Advanced Stage

Mirenco, Inc. proprietary

Legend - Annual Gallons of Fuel
Estimated values
Actual values



Evaluation Date: 8/4/2011

	Equipment Number	Eng Pos.	Stack Position	Vehicle Type	Vehicle Mfr	Vehicle Model	Eng Year	Eng Mfr	Engine Model	Hrs	Baseline Evaluation Date	Baseline DPM (%)	Baseline Instl	Baseline Annual DPM (lb)	Baseline Annual Fuel Loss (Gal)	Current Evaluation Date	Current DPM (%)	Current Instl	Current Annual DPM (lb)	Current Annual Fuel Loss (Gal)	Annual Gallons of Fuel*
19	4011	Single	Left	Dozer	Caterpillar	D11T	2008	CAT	C32	E	8/5/2011	16.0	1.0	1,203	2,969	8/5/2011	16.0	1.0	1,203	2,969	93,081
20	4011	Single	Right	Dozer	Caterpillar	D11T	2008	CAT	C32	E	8/5/2011	14.0	1.0	1,356	3,354	8/5/2011	14.0	1.0	1,356	3,354	93,081
21	4018	Single	Left	Dozer	Caterpillar	D11R	2000	CAT	3508	E	8/5/2011	8.0	2.0	3,297	8,142	8/5/2011	8.0	2.0	3,297	8,142	103,182
22	4018	Single	Right	Dozer	Caterpillar	D11R	2000	CAT	3508	E	8/5/2011	8.0	4.0	3,394	8,385	8/5/2011	8.0	4.0	3,394	8,385	103,182
23	5010	Single	Left	Dozer	Caterpillar	D10T	2009	CAT	C27	E	8/4/2011	13.6	1.0	635	1,569	8/4/2011	13.6	1.0	635	1,569	57,797
24	5010	Single	Right	Dozer	Caterpillar	D10T	2009	CAT	C27	E	8/4/2011	11.4	1.0	618	1,527	8/4/2011	11.4	1.0	618	1,527	57,797
25	5011	Single	Left	Dozer	Caterpillar	D11R	2002	CAT	3508	E	8/4/2011	8.0	4.0	4,069	10,057	8/4/2011	8.0	4.0	4,069	10,057	94,453
26	5011	Single	Right	Dozer	Caterpillar	D11R	2002	CAT	3508	E	8/4/2011	8.0	3.0	2,799	6,837	8/4/2011	8.0	3.0	2,799	6,837	94,453
27	5012	Single	Left	Dozer	Caterpillar	D11R	2004	CAT	3508	E	8/4/2011	12.4	1.0	1,218	3,003	8/4/2011	12.4	1.0	1,218	3,003	94,453
28	5012	Single	Right	Dozer	Caterpillar	D11R	2004	CAT	3508	E	8/4/2011	12.4	1.0	665	2,433	8/4/2011	12.4	1.0	665	2,433	94,453
29	5013	Single	Single	Dozer	Caterpillar	D7R	2001	CAT	3306	M	8/4/2011	11.1	0.0	1,070	2,642	8/4/2011	11.1	0.0	1,070	2,642	47,613
30	5014	Single	Left	Dozer	Caterpillar	D11R	2009	CAT	3508	E	8/5/2011		2.0	3,140	7,750	8/5/2011		2.0	3,140	7,750	103,182
31	5014	Single	Right	Dozer	Caterpillar	D11R	2009	CAT	3508	E	8/5/2011		2.0	2,820	6,959	8/5/2011		2.0	2,820	6,959	103,182
32	5015	Single	Left	Dozer	Caterpillar	D11R	2008	CAT	3508	E	8/5/2011		2.0	5,091	12,422	8/5/2011		2.0	5,091	12,422	103,182
33	5015	Single	Right	Dozer	Caterpillar	D11R	2008	CAT	3508	E	8/5/2011		2.0	3,993	9,764	8/5/2011		2.0	3,993	9,764	103,182
34	5017	Single	Single	Dozer	Caterpillar	D6T	2005	CAT	C15	E	8/4/2011	8.0	1.0	318	795	8/4/2011	8.0	1.0	318	795	43,732
35	5018	Single	Single	Dozer	Caterpillar	D9N	1995	CAT	3408	M	8/5/2011		8.0	4,505	11,123	8/5/2011		8.0	4,505	11,123	92,726
36	5019	Single	Single	Grader	Caterpillar	163	1997	CAT	3406	M	8/4/2011	14.0	2.0	413	1,016	8/4/2011	14.0	2.0	413	1,016	41,286
M	Evaluations										Totals/Averages										

Legend - Engine Combustion Status
Green - Acceptable
Yellow - Early Stage
Red - Advanced Stage

Mirenco, Inc. proprietary

Legend - Annual Gallons of Fuel
Estimated values
Actual values

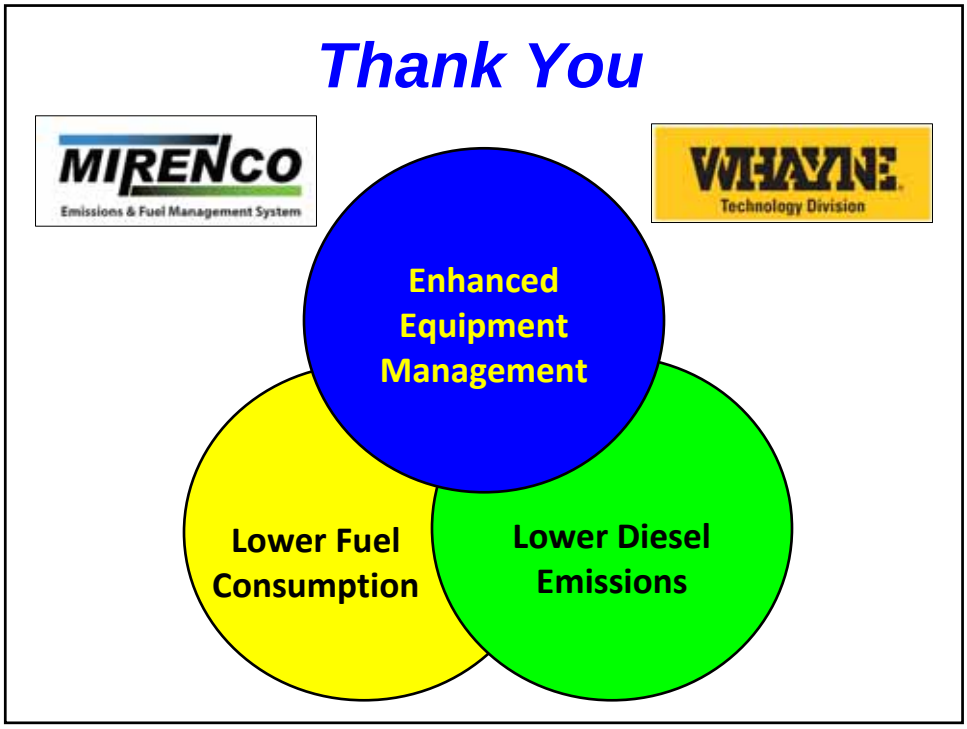
10 Machines identified to proceed with Mirenco recommended repairs & retest machines upon completion of repair

Unit	Model	Recommended Repair
5036	EX3600	Evaluation results indicate the engine is injecting more fuel than it can burn during engine acceleration. Hydrocarbon numbers are above normal indicating diesel fuel or engine oil vapor have been measured in the five gas sample. Recommend replacing the turbo boost sensor then conduct a tune up after performing a fuel injector cut-out test for potential fuel injector atomization problem. Change engine oil and oil filter a bit more frequent for this engine prior to the next MDEP evaluation.
5003	EH1700	Evaluation results indicate the engine is injecting more fuel than it can burn during engine acceleration. Hydrocarbon is above normal indicating diesel fuel vapor is measured in the five gas results. Recommend conducting a fuel injector cut out test to measure individual injector performance.
5005	EH1700	Evaluation results indicate the engine is injecting more fuel than it can burn during engine acceleration. Recommend tuning the fuel injection to match the engine's real-time ability to burn fuel during accelerations.
5042	D75KS	Evaluation results indicate the engine is injecting more fuel than it can burn during engine acceleration. Carbon Monoxide results are above normal during engine idle indication a engine oil control problem. Recommend checking for potential early stage turbo oil seal leak to start with then a fuel injector cut-out test and engine tune-up
5062	773B	Evaluation results indicate the engine is injecting more fuel than it can burn during engine acceleration. Carbon Monoxide is above normal indicating some engine oil vapor was measured in the five gas sample. Recommend adjusting the engine's air/fuel control to reduce fuel loss during engine accelerations. Check turbo oil seals for leaks
4015	D11R	Evaluation results indicate the engine is injecting more fuel than it can burn during engine acceleration. Recommend installing C-Max to reduce fuel loss.
5011	D11R	Evaluation results indicate the engine is injecting more fuel than it can burn during engine acceleration. Recommend tuning and adjust the fuel injection to match the engine's real-time ability to burn fuel during accelerations. Note - C-Max is an option for this engine
5014	D11R	Evaluation results indicate the engine is injecting more fuel than it can burn during engine acceleration. Recommend tune and adjusti the fuel injection to match the engine's real-time ability to burn fuel during accelerations. Note - C-Max is an option for this engine.
5015	D11R	Evaluation results indicate the engine is injecting more fuel than it can burn during engine acceleration. Recommend tune up and adjust the fuel injection to match the engine's real-time ability to burn fuel during accelerations. Note - C-Max is an option for this engine.
5019	D9N	Evaluation results indicate the engine is injecting more fuel than it can burn during engine acceleration. Recommend replacing or repair engine air-fuel control then adjust the engine's air/fuel control to reduce fuel loss during engine accelerations.

2011 Fuel Study Results

				Prior To Tuneup	After Tuneup	%
				Jan - Oct	Nov - Dec	
	ID	Model	Type	Ave Gal/Hr		
1	5003	EH1700	Haul Truck	14.1	15.4	-9.7%
2	5005	EH1700	Haul Truck	14.1	15.1	-7.5%
3	5011	D11R	Dozer	33.1	30.9	6.6%
4	5014	D11R	Dozer	35.7	35.0	2.0%
5	5015	D11RCD	Dozer	35.6	32.8	8.1%
6	5019	D9N	Dozer	10.6	10.3	2.9%
7	5036	EX3600	Shovel	68.3	55.0	19.4%
8	5042	D75K	Drill	23.2	21.7	6.2%
9	5062	773	Water Truck	8.1	5.0	38.2%
10	4015	D11R*	Dozer	36.4	32.2	11.6%
	Summary			279.1	253.4	
				9.2% Fuel Reduction		

Fuel Savings 9.2%		
Annual Gallons saved		139,536
Fuel Price	$	3.50
Annual Savings	$	488,376
Testing	$	(12,000)
Tuneups	$	(20,000)
Net Savings	$	456,376


Thank You
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Lower Fuel Consumption
Lower Diesel Emissions