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FINAL REPORT ON LANDFILL DIESEL VEHICLE EMISSION TESTING

Performed for:
AMERICAN REF-FUEL OF SEMASS
AT THEIR CARVER-MARION-WAREHAM LANDFILL

Client Reference No: 083r4891
CleanAir Project No: 9455
Revision 1: February 4, 2004

To the best of our knowledge, the data presented in this report are accurate and complete and error free, legible and representative of the actual emissions during the test program.

Submitted by,

Jordan Szafranski

Reviewed by:

Larry Golden

PROJECT OVERVIEW

This report summarizes the Diesel vehicle emission data collected by CleanAir Engine Services for the SEMASS Partnership at their Carver-Marion-Wareham (CMW) Landfill. The landfill is located in Carver, MA.

The purpose of the testing was to demonstrate the effects on exhaust emissions and fuel efficiency following the installation of an inline fuel catalyst device on several landfill vehicles. This was required to comply with Provision 17 of their Final Permit dated March 14, 2003 for Authorization to Operate (ATO) Phase VIA. CleanAir was contracted to perform the fine particulate (PM 2.0) sampling. The pre-retrofit testing took place on November 17, 18 and 19, 2003. The post-retrofit testing took place a month later on December 16 and 17, 2003.

Larry Golden of CleanAir Engine Services coordinated the testing with Matt Sears and Dan Peters of American Ref-Fuel. CleanAir's responsibility was the monitoring of fine particulate emissions (PM 2.0) from the selected vehicles. Rentar Environmental, the vendor of the catalytic devices, performed gaseous emissions and opacity sampling. The Rentar Environmental representatives were Bob Ketter and Michael Gray.

A list of the vehicles chosen for the study is shown below (pictures of each are included in the Appendix).

- **Vehicle Year, Make, Model – Type – Serial Number**
- 1992 Volvo L-160 – Front End Loader - 60509
- 1993 Caterpillar 826C – Landfill Compactor – 87X1738
- 1995 Caterpillar D-8N – Bulldozer – 9TC2103
- 1996 Caterpillar D-6H – Bulldozer - 3ZF6099
- 1998 Caterpillar 315BL – Excavator – 3AW1147

* Since the in-line fuel catalyst was installed on the Cat D-6H Bulldozer in Nov. 2002 no emissions work was performed on that vehicle. Only fuel economy will be checked.

One set of field measurements was conducted at normal, non-load, engine idle (Steady State – SS). Another set of data were taken during a Snap Idle or Snap Puff cycle, where the engine is taken from idle to full throttle and back down again all in a 20 second event.

PROJECT OVERVIEW

In addition to the steady state and snap idle tests, the D-8N Bulldozer underwent a simulated load test. The simulated load testing was performed by towing a Mack Truck 10-wheel dump truck loaded with clay, to a gross vehicle weight of 75,800 pounds, along a designated track, consisting of a portion of the landfill's perimeter road, and back again. The entire loop took about 20 minutes and each test was repeated three times.

The testing parameters, methodology and frequency were determined and agreed to by representatives from American Ref-Fuel, SEMASS Partnership and the Solid Waste Management Section of the Massachusetts Department of Environmental Protection. A thorough discussion of methodology is included in Section 4 of this report.

Coordinating the field testing were:

Matt Sears - American Ref-Fuel of SEMASS
Dan Peters - American Ref-Fuel of SEMASS
David Ellis - Solid Waste Management Section, MADEP
Art Dean - Clean Air Engineering (Nov)
Jordan Szafranski - Clean Air Engineering (Dec)

RESULTS

Results for all vehicles are shown below in table and graph format. Results are grouped by test vehicle, not the test procedure. Each table shows a cumulative average from three pre-retrofit tests and three post-retrofit tests, a total particle reduction or increase, and a percent change. The tables displaying results from the Snap Idle tests break down the data one step further and show the particle count from the snap puff and the wide open throttle (WOT) independent of each other. Accompanying each table is a graphic representation, which simplifies the interpretation of the resulting data. Note that the graph y-axis is logarithmic to aid in interpreting the data. All table values are presented in millions of particles, and all graphs are total particles. Each bin size measurement is in microns; 0.000001 meters (i.e. 0.30 microns = 0.0000003 meters). A full description of each test procedure is outlined in Section 4, Methodology.

As the data shows, all of the vehicles tended to show a reduction in fine particulate over the range of the instrument although some minor increases were noted in varying bin sizes. Some increases were noted in the two smaller bin sizes, .3-.39 and .4-.49 microns, during the transient testing of the D-8N Bulldozer. This change could have resulted from differing test track conditions, insufficient warm up time, or even weather. However, it is not clear exactly why this occurred and only further testing would provide an answer.

RESULTS

CATERPILLAR 315BL EXCAVATOR

Table 2-2:
Snap Idle and WOT

Summary: Caterpillar 315BL Excavator

	Bins>	.3u - .39u	.4u - .49u	.5u - .64u	.65u - .79u	.8u - .99u	1.0u - 1.59u	1.6u-1.99u	> 2.0u
Pre Avg.	Snap Puff	101.180	30.647	14.865	4.175	1.526	1.570	0.292	0.045
	WOT	20.392	5.554	3.406	1.329	0.479	0.337	0.045	0.112
Post Avg.	Snap Puff	32.427	11.947	4.766	1.070	0.153	0.275	0.061	0.000
	WOT	6.506	2.917	0.993	0.367	0.061	0.000	0.031	0.000

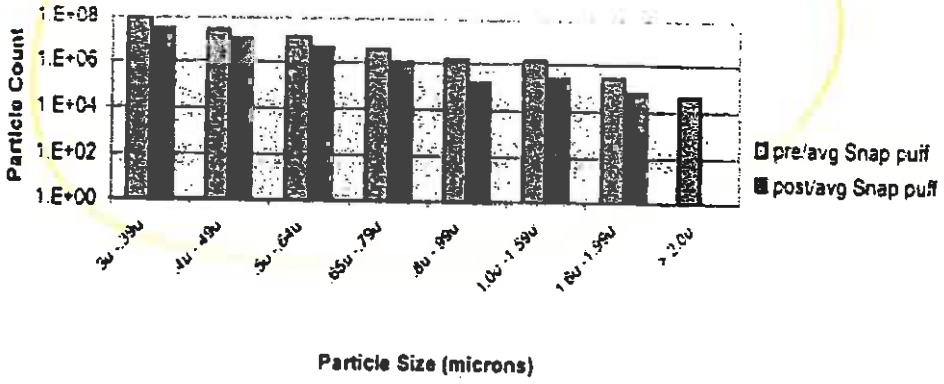
Particle reduction

	Bins>	.3u - .39u	.4u - .49u	.5u - .64u	.65u - .79u	.8u - .99u	1.0u - 1.59u	1.6u-1.99u	> 2.0u
Differential	Snap Puff	68.752	18.700	10.099	3.106	1.373	1.295	0.231	0.045
	WOT	13.888	2.637	2.412	0.962	0.418	0.337	0.014	0.112
% Reduction	Snap Puff	67.951	61.015	67.941	74.377	89.982	82.481	79.038	100.000
	WOT	68.102	47.486	70.842	72.390	87.249	100.000	31.872	100.000

Table values in millions of particles

Graph 2-2:
Snap Idle

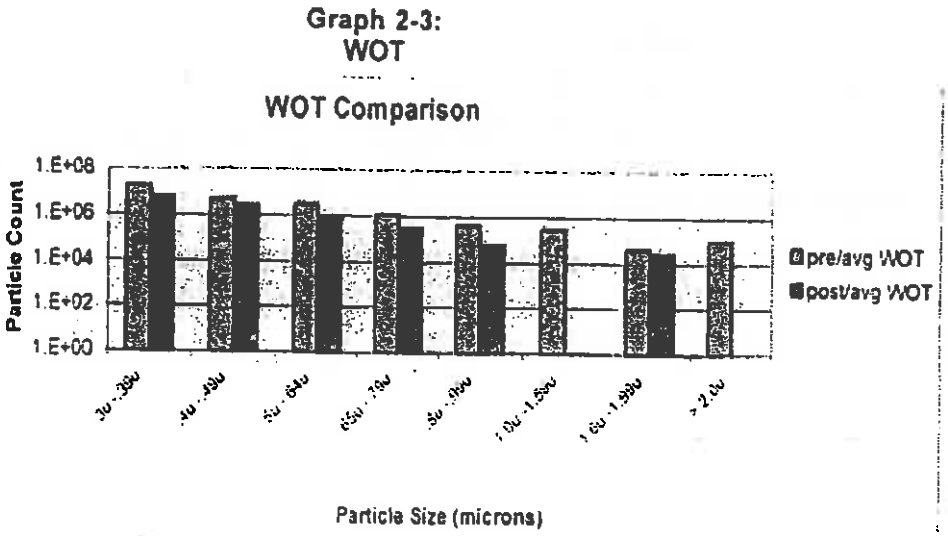
Snap Puff Comparison



RESULTS

CATERPILLAR 315BL EXCAVATOR

Graph 2-3:
WOT



RESULTS

VOLVO L-160 LOADER

Table 2-6:
Snap Idle and WOT

Summary: Volvo L-160 Front Loader

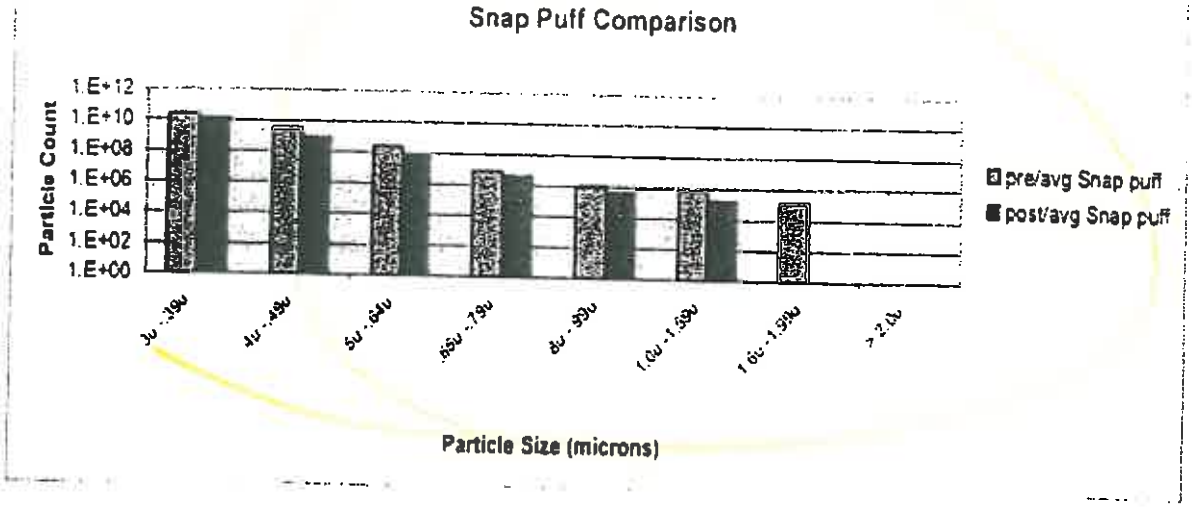
	Bins>	.3u - .39u	.4u - .49u	.5u - .64u	.65u - .79u	.8u - .99u	1.0u - 1.59u	1.6u-1.99u	> 2.0u
Pre Avg.	Snap Puff	26993.045	3811.418	276.879	8.061	0.984	0.709	0.159	0.000
	WOT	599.454	195.536	26.904	1.802	0.418	0.167	0.032	0.000
Post Avg.	Snap Puff	12906.922	891.789	78.508	4.004	0.428	0.153	0.000	0.000
	WOT	647.165	64.588	10.411	1.345	0.092	0.061	0.000	0.000

Particle reduction

	Bins>	.3u - .39u	.4u - .49u	.5u - .64u	.65u - .79u	.8u - .99u	1.0u - 1.59u	1.6u-1.99u	> 2.0u
Differential	Snap Puff	14086.123	2919.649	198.370	4.056	0.556	0.547	0.159	0.000
	WOT	-47.711	130.948	16.493	0.457	0.326	0.106	0.032	0.000
% Reduction	Snap Puff	52.2	76.6	71.6	50.3	56.5	79.2	100.0	NA
	WOT	-8.0	67.0	61.3	25.4	78.0	63.3	100.0	NA

Table values in millions of particles
Negative values indicate an increase in particles

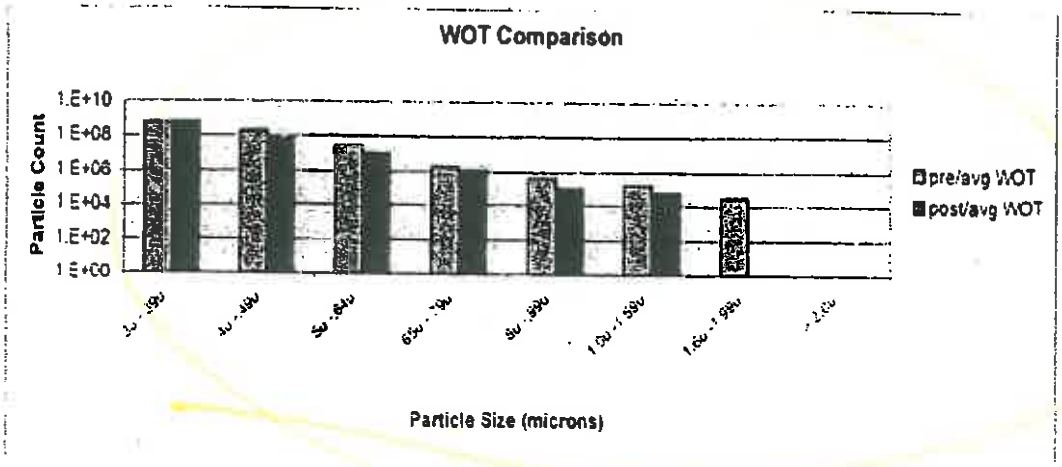
Graph 2-8:
Snap Idle



RESULTS

VOLVO L-160 LOADER

Graph 2-9:
WOT



RESULTS

CATERPILLAR D-8N BULLDOZER

Table 2-8:
Snap Idle and WOT

Summary: Caterpillar D-8N Bulldozer

	Bins>	.3u - .39u	.4u - .49u	.5u - .64u	.65u - .79u	.8u - .99u	1.0u - 1.59u	1.6u - 1.99u	> 2.0u
Pre Avg.	Snap Puff	22021.642	4731.622	831.256	119.356	33.476	25.633	3.508	1.650
	WOT	966.503	293.869	72.239	13.434	4.444	3.233	0.351	0.255
Post Avg.	Snap Puff	4976.437	222.943	13.956	0.586	0.306	0.092	0.061	0.061
	WOT	307.622	54.626	7.559	0.978	0.153	0.183	0.000	0.061

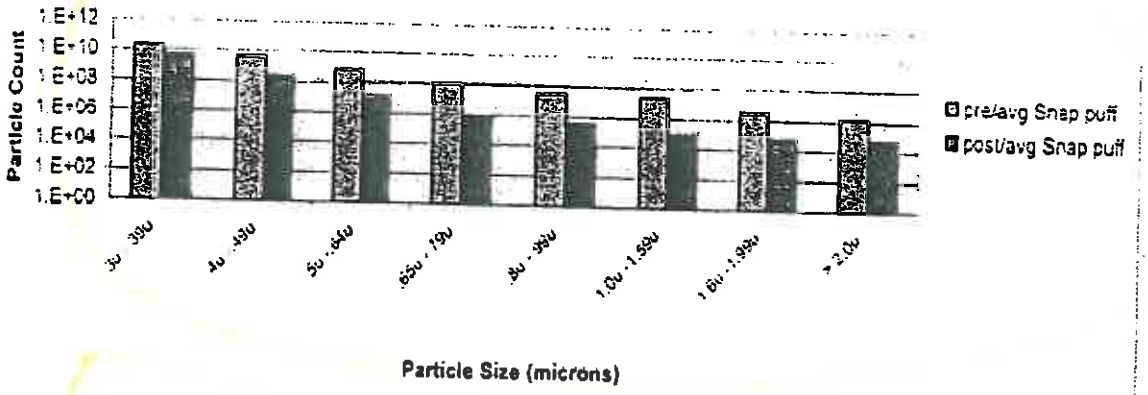
Particle reduction

	Bins>	.3u - .39u	.4u - .49u	.5u - .64u	.65u - .79u	.8u - .99u	1.0u - 1.59u	1.6u - 1.99u	> 2.0u
Differencial	Snap Puff	17045.205	4508.679	817.300	118.469	33.170	25.542	3.447	1.589
	WOT	658.882	239.274	64.680	12.456	4.291	3.050	0.351	0.194
% Reduction	Snap Puff	77.4	95.3	98.3	99.3	99.1	99.5	98.3	96.4
	WOT	68.1	81.4	89.4	92.7	96.6	94.3	100.0	76.0

Table values in millions of particles

Graph 2-11:
Snap Idle

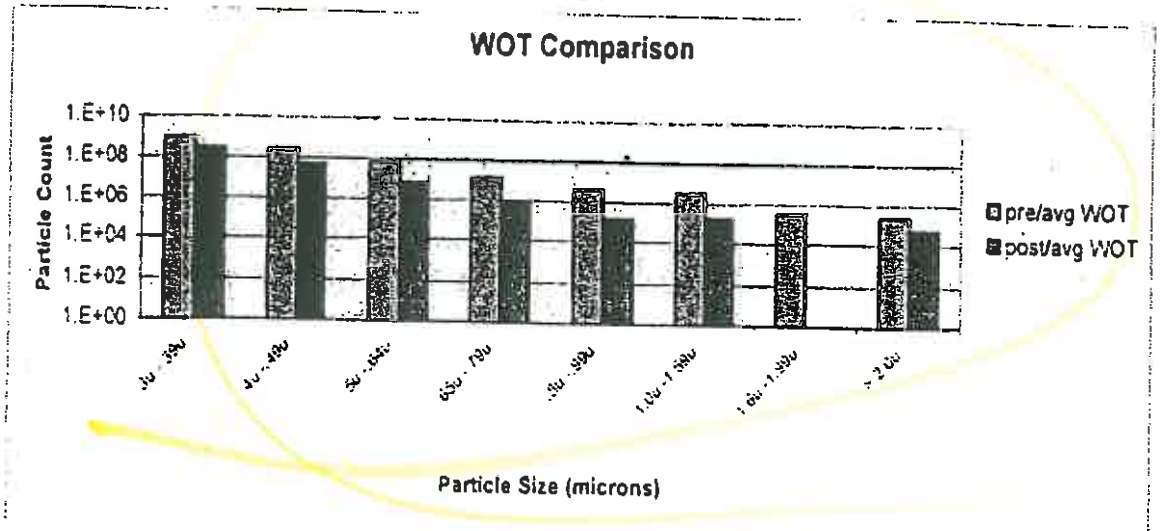
Snap Puff Comparison



RESULTS

CATERPILLAR D-8N BULLDOZER

Graph 2-12:
WOT



DESCRIPTION OF INSTALLATION

American Ref-Fuel operates the Carver-Marion-Wareham (CMW) landfill in Carver, MA. Several diesel vehicles are used in the daily operation of this landfill and the testing was performed on five (5) of those vehicles.

Part of Provision 17 of the ATO requires the use of low-sulfur diesel fuel in all the diesel-powered vehicles at the CMW landfill site. The fuel supplier for the CMW landfill is Canal Fuel Company of Sagamore, MA. According to American Ref-Fuel, Canal has continuously been delivering low-sulfur highway diesel fuel oil #2 to the CMW landfill site since before the ATO dated in March of 2003.

Retrofit devices, manufactured by Rentar Environmental, Inc., were installed on the fuel line of each vehicle after a complete set of baseline data was captured (the Nov. tests).

Each vehicle was then operated in its normal fashion for the break-in periods. The field crews were redeployed in December 2003 and the sampling was repeated, matching the procedures of the baseline testing of November 2003 as closely as possible. Hours of operation of each vehicle, pre- and post-retrofit are shown below in Table 3-1.

Table 3-1:
Installation of Fuel Catalyst Units in Diesel Powered Equipment

Vehicle Year, Make, Model and Type	Post 1st Round Testing: Date of Fuel Catalyst Installation:	Machine Hours	2nd Round Testing: Date of 2nd Round Testing:	Machine Hours	Fuel Catalyst Break-In Period (Hours)
1992 Volvo L-180 Front-End Loader	12/3/03	14,332	12/16/03	14,449	117
1993 Caterpillar 826C Compactor	11/24/03	15,481	12/16/03	15,533	52
1995 Caterpillar D-8N Bulldozer	11/25/03	17,942	12/16/03	18,047	105
1996 Caterpillar D-6H Bulldozer *	11/19/02	19,742	12/17/03	22,784	3,042 *
1999 Caterpillar 315BL Excavator	11/18/03	4,840	12/16/03	4,870	30

Notes: * 1st Round "Pre-Retrofit" testing could not be conducted for the Caterpillar D-6H Bulldozer since the fuel catalyst was installed during November 2002, prior to the start of the vehicle testing program.

The particulate sampling was conducted at the exhaust outlet on each of the diesel vehicles. Pictures showing the sampling apparatus in place on some of the vehicles are shown in Figures 3-1 through 3-5.

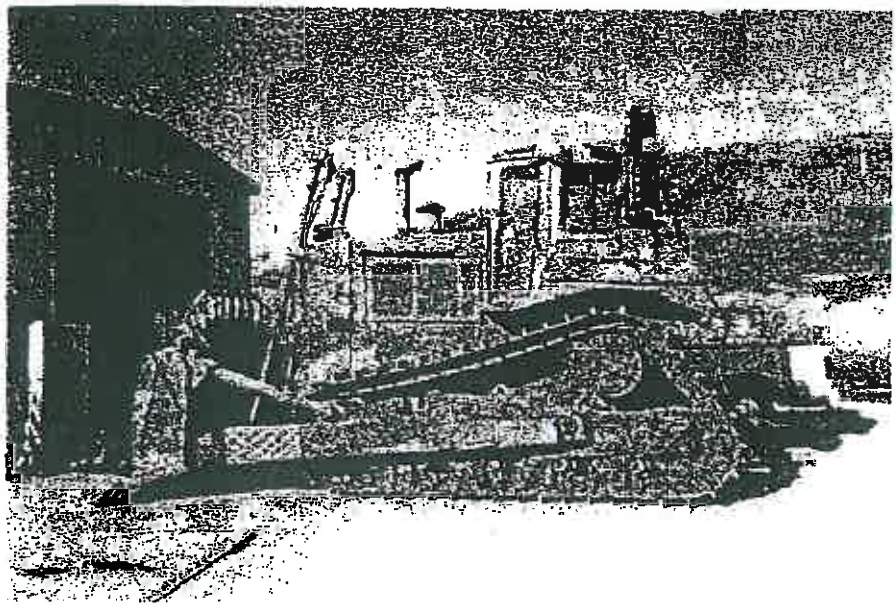


Figure 3-1:
Cat D-8N prior to Steady State Testing

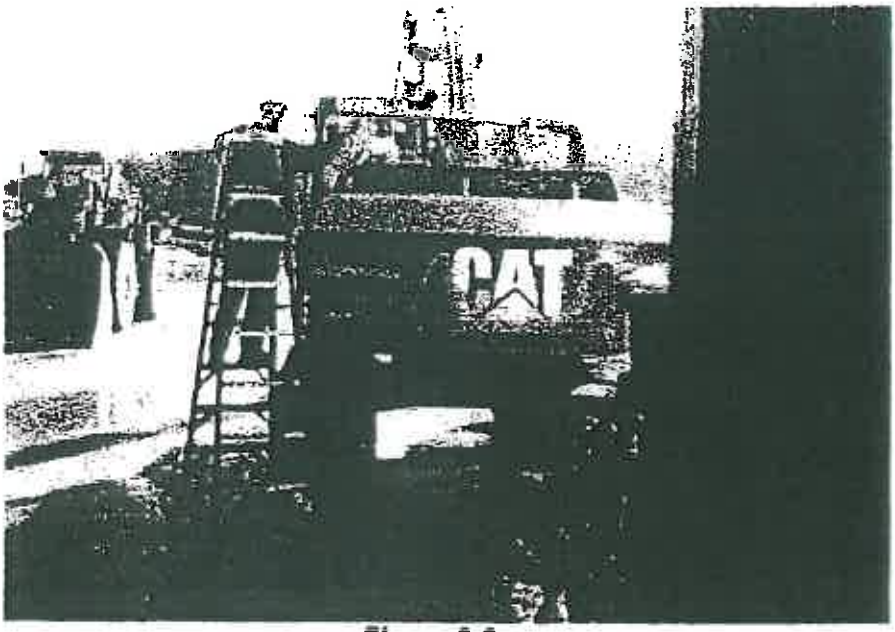


Figure 3-2:
Cat 315BL During Steady State Testing

DESCRIPTION OF INSTALLATION

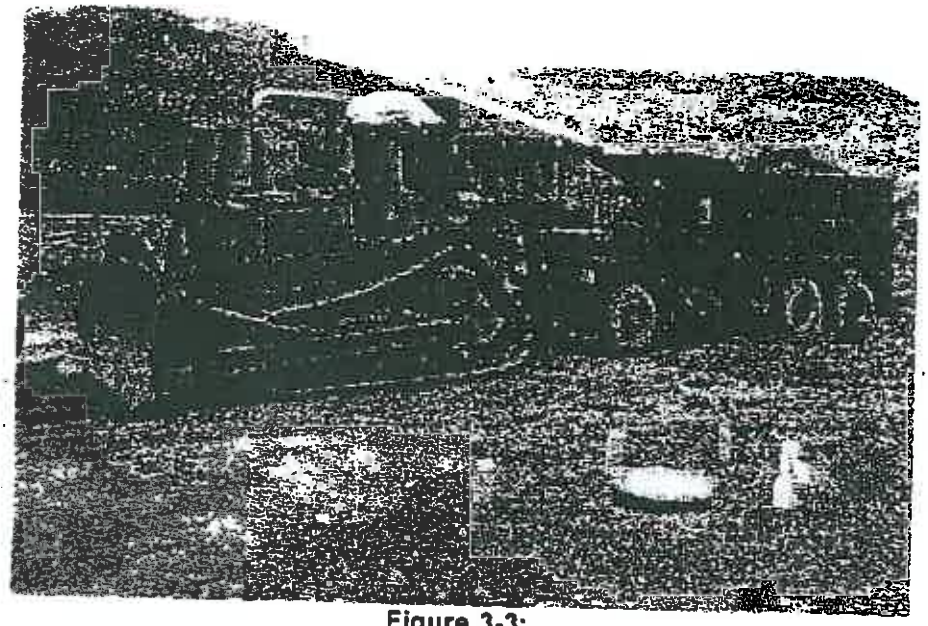


Figure 3-3:
Cat D-8N Bulldozer Pulling Load
Note: Exhaust Extension and PM-300 Under Plastic

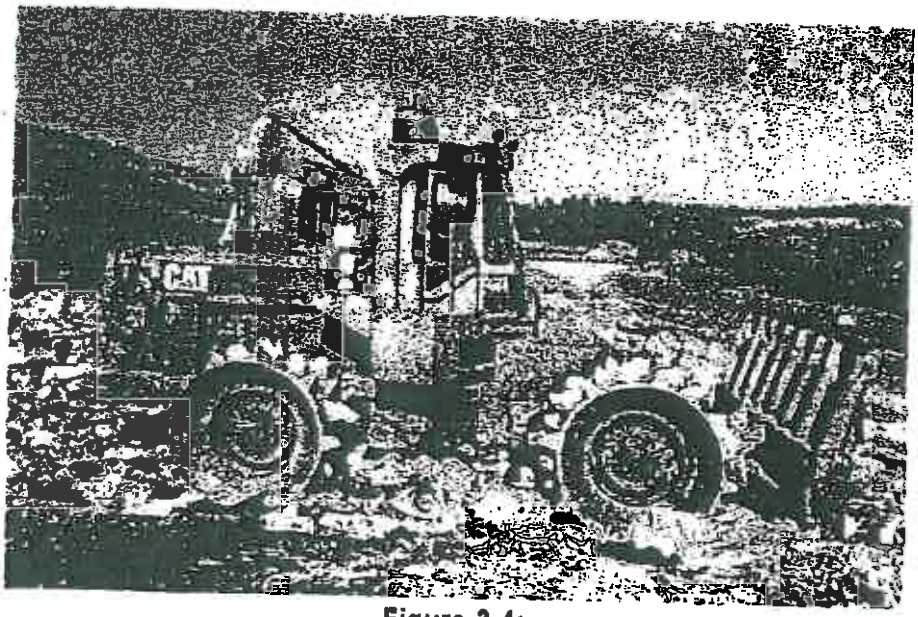


Figure 3-4:
Cat 826C Compactor

DESCRIPTION OF INSTALLATION

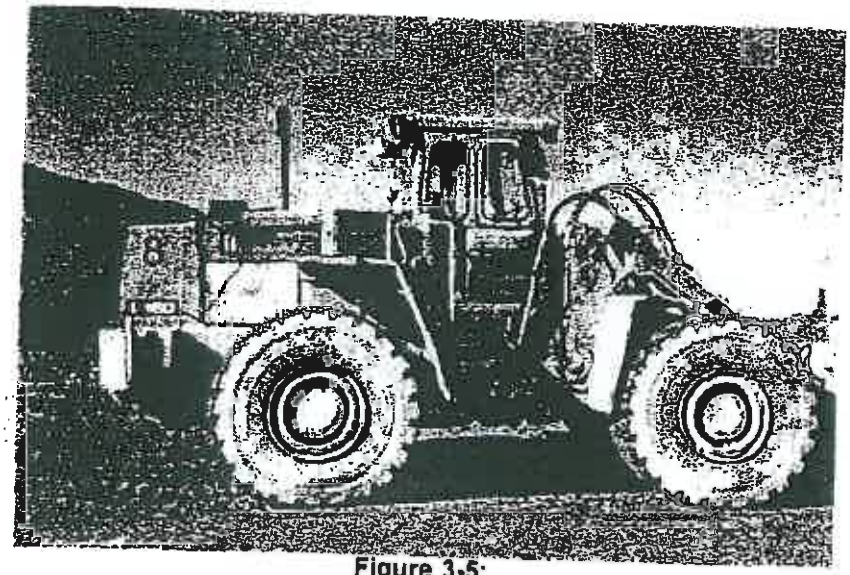


Figure 3-5:
Volvo L-160 Loader

METHODOLOGY

CleanAir used the PM-300 particulate analyzer manufactured by Sensors, Inc. of Saline, MI. The system uses a well-known laser light scattering counting technique to detect and measure particles in the 300nm to 2+ micron range. Exhaust gas is drawn into the analyzer through a heated sample line and a temperature controlled, dilution system equipped with a high precision mass flow controller. The analyzer generates a family of curves, each representing a specific particle size over the full operating range of the instrument. The data-sampling rate of the unit is 1 second enabling resolution of transient events.

The particle counter type is an optical scattering pulse counting near infrared (NIR) laser. The resulting bin size cuts are 0.3, 0.4, 0.5, 0.65, 0.8, 1.0, 1.6, and 2+ microns. The unit is calibrated using spherical particles of uniform density and therefore is not a direct reading instrument. Diesel particulate is not spherical nor of uniform density, but it can be classified behaviorally as the measured particles react similarly to the calibration particles when contacted by the laser. The most meaningful data captured in this study is the differential data comparing before and after retrofit particle emissions and for this purpose the PM-300 works well.

A description of each test condition is given below.

Steady State Tests – Each vehicle was started and fully warmed up before the testing apparatus was installed. This allowed the engines oil and cooling system to reach a steady operating temperature. The steady state tests were run at idle and lasted for about 15 minutes each. Data was captured over the full 15 minutes and from that 10 minutes of data were averaged for the results.

Snap Idle Tests - Following the three steady state tests, after the vehicles have been idling for about 50 minutes or so, we conducted three Snap Idle tests back to back. Each test lasted only 20 seconds and included sampling from idle through wide open throttle. From the test only 10 seconds of data was used. Five (5) seconds of the snap idle which entails the transition from idle to full throttle, and the next five (5) seconds where the vehicle has stabilized itself at full throttle.

Transient Load Testing – Transient testing was conducted on the Caterpillar D-8N. Load testing is the best method to simulate real work conditions of a vehicle. This test included pulling a known amount of rolling weight through a set course around the perimeter of the landfill facility. Each test lasted approximately 20 minutes.