Particulate and Carbon Dioxide Emissions From Diesel Fires: The Mobile 1997 Experiments

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Abstract

A series of 12 mesoscale burns were conducted in 1997 to assess fire-resistant booms and to study various aspects of in-situ burning of diesel oil. Extensive sampling and monitoring of these burns were conducted to determine the emissions. This was done at ten downwind ground stations, one upwind ground station and at six side stations. Particulate samples in air were taken and analysed for Polycyclic Aromatic Hydrocarbons (PAHs). Particulates in the air were measured by several means and found to be greater than recommended exposure levels only up to 50 metres downwind at ground level. Comparisons were made between total particulates, and fractions at 10 µm and at 2.5 µm. Additional comparisons were made between real-time monitors and approved fixed devices. Furthermore comparison of particulate sizes and instrumentation methods were made. Combustion gases, including carbon dioxide, did not reach exposure level maximums. These gases were emitted over a broad area around the fire and are not directly associated with the plume trajectory. Volatile organic compound (VOCs) emissions were measured in Summa canisters.

This paper reports on the measurements of particulates and carbon dioxide at the burns. It was found that the particulates are emitted at low levels by these smaller burns and that the maximum extent of hazardous levels was about 50 metres in terms of PM-10 (particulates of size less than 10 µm). Both electronic instruments and

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standard filter-collection devices were used at six stations for TSP (Total Suspended Particulate) for PM-10 and PM-2.5. It was found that the amount of the TSP corresponded to the amount of both PM-10 and the PM-2.5. The amount of the smaller particulates was generally larger than expected, possibly indicating that particles are broken down by the instrumentation. This was especially true of the DataRAM. The electronic measuring instruments, the RAM and DataRAM, yielded relatively good results for total particulate, if corrected by using background readings taken before and after the burns. They were less reliable than standard instruments for measuring PM-10 and PM-2.5.

Carbon dioxide was measured at 13 stations, and at 7 of these stations was measured at 4 different elevations to establish the three-dimensional distribution. It was found that the highest concentrations of carbon dioxide were found most frequently at the lowest levels or at the 2-metre level depending on ambient conditions. The distribution of carbon dioxide was fitted to a 3-dimensional model.

1.0 Introduction

Seven years of intensive laboratory and tank testing on the in-situ combustion of oil have indicated that the nature and concentrations of atmospheric emissions from in-situ burning of oil offshore will normally be an acceptable tradeoff when weighed against the environmental risks and cleanup costs of shoreline contamination.

In 1991, U.S. MMS began the sponsorship, in cooperation with several agencies, of a series of mesoscale burn tests. These tests were designed to measure a series of physical parameters as well as emissions. The facilities of the Fire and Safety Test Detachment at Sand Island situated at upper Mobile Bay, Alabama, were used. Environment Canada and the U.S. Environmental Protection Agency cooperated to set up a series of instruments and samplers to monitor all suspect emissions at this and several subsequent trials. In 1992, a similar series of experiments was set up to monitor these burns. In 1993, a major experiment was conducted offshore Canada to measure crude oil emissions. Analyses of these trials are reported in the literature (Fingas, *et al.*, 1993; Fingas *et al.*, 1994a,b; Fingas *et al.*, 1995). In 1994, three large diesel burns were conducted at Mobile to test a new air-measuring package (Fingas *et al.*, 1996). This paper reports on the data from the 1997 trials involving diesel fuel. The burns themselves and the boom tests were sponsored by the United States Coast Guard for the purpose of testing fire-resistant containment booms. Environment Canada and the Environmental Protection Agency sponsored the emission-measuring campaign.

2.0 Experimental

The primary goal of this series of test burns was the evaluation of five fire-resistant booms under American Society for Testing and Materials (ASTM) protocols. In total five booms were tested and twelve in-situ burn experiments were performed. To carry out this project a new test tank was constructed on Little Sand Island. The tank had dimensions of 9.2 m (30 feet) width by 30.8 m (100 feet) length by 1.5 m (5 feet) depth. Wave generating equipment was installed at one end of the tank. Provisions were made to install the test boom in a circular pattern about the center of the tank. A supply line transported the fuel from the storage tank to the center of the test tank. A 38,000 L (10,000 US gallon) storage tank was located on the island to supply the fuel for the tests. The discharge outlet in the test tank was located near the center of the boom at the interface of the surface and water.

During these burns the Emergencies Science Division (ESD) of Environment Canada (EC), in collaboration with the U.S. Environmental Protection Agency (EPA-ERT) and the United States Coast Guard Gulf Strike Team (USCG-GST), performed air, water and fuel monitoring and/or sampling. Air monitoring was carried out using an array of stationary air sampling equipment and real-time monitoring equipment. Water and diesel samples were collected manually from the test tank and stored for subsequent analysis. The USCG-GST monitored the concentration of the particulates in air using equipment on boats located downwind from the test facility. The boats were located between 150 and 600 m from the island. Measurements and samples taken on the boats focussed on smoke particulate deposition at surface level. Instrumentation included the DataRAM monitor for particulate analysis.

Environment Canada and the EPA supplied a variety of ground based instruments for sampling the air. In total there were eighteen or nineteen sampling stations, depending on the burn. Of these, a maximum of two were located on the USCG-GST boats and seventeen were located on land around the test tank. Sampling stations formed a grid pattern surrounding the test tank with the majority situated on the downwind side. Monitoring stations extend from 30 m to 90 m away from the center of the test tank. As well, three meteorological monitoring stations were positioned 90 m downwind from the test tank, 90 m upwind from the test tank and 75 m to one side of the test tank. Water, diesel and residue samples were collected at specified time periods throughout the testing program. Table 1 summarizes the instrumentation used and their locations around the test tank. Figure 1 illustrates the site layout with monitoring locations marked. Due to the lack of a sufficient number of Summa canisters and carbon dioxide meters modifications to the original instrument array were required. Summa canisters and carbon dioxide monitors were not placed at station DW2A, DW2B, DW4B, DW2C, DW3C, DW5B, and DW6B. Following the first series of burns the carbon dioxide monitors at station DW4B were repositioned to the side stations.

2.1 Real-time Air Monitoring - MIE RAM and DataRAM Portable Real-time Aerosol Monitor

The RAM and DataRAM are commercially-available piece of equipment commonly used in the occupational health and safety industry. The RAM (MIE Inc, Bedford MA) portable real-time aerosol monitor allows measurement of aerosols and particulates continuously. The advantage of time information is the potential to correlate particulates with specific burn events, such as when the burn is initiated or extinguished.

Air is continuously drawn through the RAM sensor chamber at a rate of 2 L/minute. The instrument uses a pulsed Ga As semi-conductor LED to generate a near-infrared pulse centered at 940 nm. The scattered beam is detected with a silicon photo-voltaic-type diode with an integral low noise amplifier. The detector responds to scattered light deflected by 45-95 degrees. Filtered air is blown across detectors

Table 1 Summary of Equipment and Placement

Equipment \ Location	UW1B 1	S1C 2	S2C 3	S3C 4	DW1C 5	DW2C 6	DW3C 7	DW1B 8	DW2B 9	DW3B 10	DW4B 11	DW5B 12 boat	DW6B 13 boat	DW1A 14	DW2A 15	DW3A 16	S3A 17	S2A 18	S1A 19	sub-total per burn	Total Equip.
CO_2 - Metrosonic	4	1	1	1	0			4	4	4	1			4			1	1	1	27	27
CO_2 - Armstrong					4			0	4	0	0			0						8	8
Summa	2	1	1	1	1			1	1	1				1			1	1	1	13	100
RAM-1	1				1	1	1	1	1	3	1			1	1	1				13	13
TSP	1				1			1	1					1						5	5
PM10	1				1			1	1					1						5	5
PM2.5	1				1			1	1					1						5	5
SO_2 Impinger	1								1											2	2
SO_2 SPM	1								1											2	2
H_2SO_4 SPM	1								1											2	2
Carbonyls	1								1											2	2
DataRAM	1				1			1	1	3		1	1	1						10	10
B&K IR										1										1	1
OP-FTIR																				1	1
Water samples																					5
Fuel sample																					1
Residue sample																					5

Target Analyte and Measuring/Sampling Equipment

	Carbon Dioxide		Particulates					Sulphur Dioxide			Carbonyls	VOC's			Total	Water	Fuel	Residue
Location	Metrosonic	Armstrong	DataRAM	RAM	TSP	PM10	PM2.5	SO_2 Impinger	SO_2 SPM	H_2SO_4 SPM	DNPH tube	Summa	B&K IR	OP-FTIR	Station	sample	sample	sample
UW1B	4		1	1	1	1	1	1	1	1	1	2			15			
S1C	1											1			2			
S2C	1											1			2			
S3C	1											1			2			
DW1C	0	4	1	1	1	1	1					1			10			
DW2C	0			1											1			
DW3C	0			1											1			
DW1B	4		1	1	1	1	1					1			10			
DW2B	4	4	1	1	1	1	1	1	1	1	1	1			18			
DW3B	4		3	3								1			12			
DW4B	1			1											2			
DW5B	0		1												1			
DW6B	0		1												1			
DW1A	4		1	1	1	1	1					1			10			
DW2A	0			1											1			
DW3A	0			1											1			
S3A	1											1			2			
S2A	1											1			2			
S1A	1											1		1	2			
Total	27	8	10	13	5	5	5	2	2	2	2	13	1	1	95	5	5	5

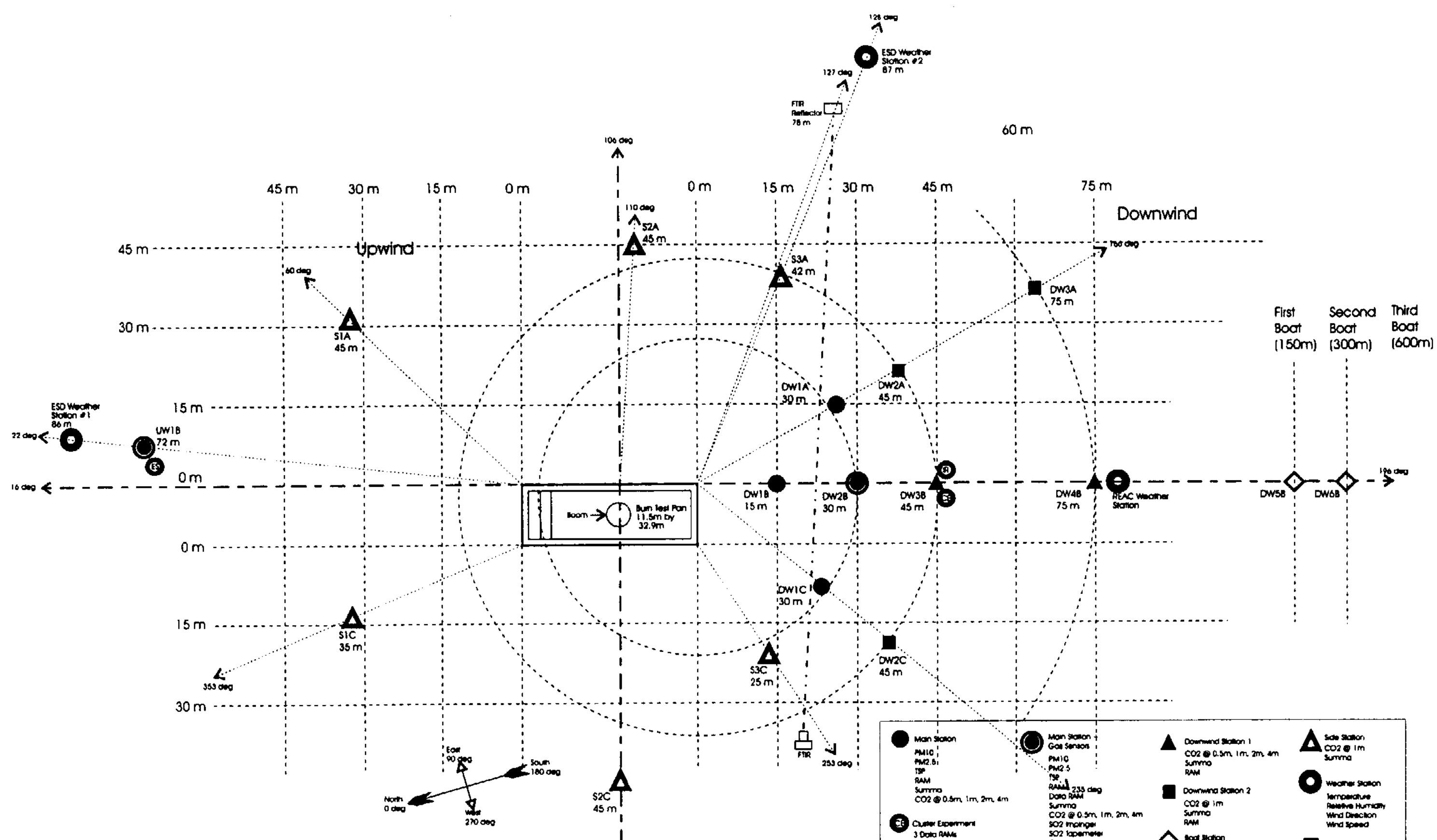

Figure 1 Mobile Burn Experiment 1997: Actual Equipment Layout

(0.3 L/minute) to keep the optical system clean. During these experiments, a cyclone pre-collector or optional omni-directional sampling head was affixed to the inlet to obtain the desired particulate fractions. The omni-directional sampling head is capable of measuring the total or 0-10 μm particulate fractions with the introduction of a 0-10 μm filter. The cyclone pre-collector limits the sampling to particulate larger than 2 μm however, the actual sampling fraction is 2-10 μm and the respective proportion of that fraction is based on a penetration curve. The two parameters that are controlled by the operator are the measuring range and the time constant. During these burn experiments the parameters were set at a measurement range of 0-20 mg/m^3 and a time constant of 2 seconds, thus sampling every 2 seconds.

For continuous monitoring tasks, such as burn tests, it was necessary to record the data using an external data logger (Campbell Scientific CR10 Data Logger). The multiple values from the RAM were averaged over a period of one minute. Controls and settings which affect the digital display have a corresponding change to the analog output. Data recorded by the data logger was converted to concentration in μg/m^3. The instrument was operated using an external solar power source. The RAM units were placed at the specified location about the sampling field and baring instrument failure, remained on station for the duration of the project.

The DataRAM (MIE Inc, Bedford MA) is an updated version of the RAM. The operating principle is the same as for the RAM. The advantage of this unit over the RAM is its improved internal data logging and processing capabilities and versatility. The apparatus is capable of employing several different sampling head configurations. These are total particulate, the 0-10μm particulate fractions or the 0-2.5 μm particulate fractions. In order to achieve the objectives of the study, each of these sampling configurations were used over the duration of the experiment. The omni-directional sampling head was used throughout the program. Measuring parameters such as the time constant and measurement range are selected during the initial set up of the unit and controlled by the internal software of the DataRAM. For this experiment the DataRAM and RAM were operated with similar air sampling rates. The instrument was operated using its internal rechargeable battery. Particulate concentration is given in units of μg/m^3 and the files were uploaded to a computer on a regular basis. The DataRAM units were placed at the specified location about the sampling field. Maintenance and calibration of the units were undertaken on a regular basis on the days during the burn program.

2.2 High Volume Air Sampler - Total Suspended Particulates (TSP)

A high volume air sampler (Andersen Graseby/GMW, Smyrna GA) was used to determine the amount of total suspended particulate matter in the air. These units are described in Canadian and American reference methods for air monitoring. Total suspended particulates are classified as particles up to 25-50 µm in size. The flow rate and geometry of this unit allows for the collection of particles ranging from 0.3 µm to 50 µm under normal operating conditions. The sample flow rate was recorded for each individual unit for each period of operation and was typically about 1.6 m^3/min with a typical volume of 100 m^3 passing through the filter each burn. The air samplers were located at the five main stations throughout the experiment (Figure 1). They were manually turned on and off in conjunction with the burn program. A tared

8" X 10" glass fibre filter (Pacwill Environmental, Hamilton ON) was placed in the apparatus and used to collect sample. Significant measures were taken to ensure adequate quality control was in place. The inside of the unit was rinsed with hexane prior to the start of the experiment. The filters were appropriately folded to reduce the risk of damage, placed in dedicated folders and stored in secure containers. Filters were weighed in a controlled environment designed and dedicated for this purpose. Background samples, field trip sample, instrument blanks etc were collected and used to evaluate the performance of the technique. After gravimetric determination of the TSP, the filters were extracted and analyzed to determine the metal, total petroleum hydrocarbon and polycyclic aromatic hydrocarbon content of the particulate.

2.3 Sampling for Respirable Particulates (PM-10)

Health and safety concerns have been expressed regarding the impact of respirable particles of less than or equal to 10 µm in size. As in the case of TSP, values for particulate matter of 10 µm size and less (PM-10) are specified in national ambient air quality standards. A PM-10 sampler (Andersen Graseby/GMW, Smyrna GA) was used to determine the amount of PM-10 sized matter in the air. These units are described in Canadian and American reference methods for air monitoring for use in determining the respirable fraction of suspended particulate matter. The sample flow rate was recorded for each individual unit for each period of operation and was typically about 1.6 m^3/min with a typical volume of 100 m^3 passing through the filter per burn. The air samplers were located at the five main stations throughout the experiment and were manually turned on and off in conjunction with the burn program. A tared 8" X 10" ultra-pure quartz fibre filter (Pacwill Environmental, Hamilton ON) was placed in the apparatus and used to collect sample. Like the TSP measurements, extensive steps were put in place to ensure quality control. The PM-10 concentration was determined gravimetrically and then the filters were extracted and analyzed to determine the metal, total petroleum hydrocarbon and polycyclic aromatic hydrocarbon content of the PM 10 particulate fraction.

2.4 Air Sampling for Respirable Particulates (PM-2.5)

Recently the US E.P.A. has announced a proposed new air quality standard calling for the measurement of fine particles smaller than 2.5µm in size. A Partisol PM-2.5 sampler (Rupprecht & Patashnick, Albany NY) was used to determine the amount of PM-2.5 sized matter in the air. These were new units and were listed as meeting EPA sampling requirements immediately prior to their use in this project. Unlike the TSP and PM-10 samplers, the PM-2.5 is operated via an internal computer system. The air samplers were located at the five main stations throughout the experiment and were manually turned on and off in conjunction with the burn program. The sample flow rate and volume of air passing through the unit was automatically calculated. This data was recorded for each individual unit for each period of operation and was typically about 1 m^3/hour (100 L/hour or 1.6 L/min) with a typical volume of 1 m^3 passing through the filter per burn. A tared 47 mm Teflon filter (CAE Instrument Rental, Palatine IL) was placed in the apparatus and used to collect sample. Like the other high volume filters, extensive steps were put in place to ensure quality control. The PM-2.5 concentration was determined gravimetrically and then the filters were extracted and analyzed to determine the metal, total petroleum hydrocarbon and polycyclic aromatic hydrocarbon content of the PM-2.5 particulate fraction.

2.5 Carbon Dioxide Monitoring - the Armstrong CD-1 and Metrosonic AQ501 Air Quality Monitor

The Armstrong CD-1 and Metrosonic AQ501 are commercially-available pieces of equipment commonly used in the occupational health and safety industry. The Metrosonic monitor (Metrosonics Inc., West Henrietta, NY) and the Armstrong CD-1 (Armstrong Monitoring Corporation, Nepean, ON) carbon dioxide monitor were used together or separately at various sampling points. A sufficient number of both types of units were in place such that a three dimensional array surrounding the burn pan was achieved (Figure 1). Individual units were located along the side of the burn pan and the sampling height was set at 1 m. Four units were located at the each of the upwind stations and at six of the downwind stations. The sampling height at these stations were 0.5 m, 1 m, 2 m and 4 m. A tower structure was assembled to permit sampling at these levels. The instruments were operated using an AC power source. The AQ501 and CD-1 units were placed at a noted location about the sampling field and baring instrument failure, remained on station for the duration of the project. Units were calibrated each morning of burn experiments.

Both the AQ501 and the CD-1 CO_2 detectors employ a non-dispersive infra-red (NDIR) detector to quantify the concentration of the gas in the air. An internal pump draws the sample at a rate of 1 L/min. A 4-m section of Teflon tubing was attached to the intake of all units. The Metrosonic unit has an internal data logger while the Armstrong instrument was connected to an external data logger (Campbell Scientific CR10 Data Logger) which were set up to record data continuously and report 1 minute averages. The instruments were turned on at an adequate time period prior to the start of the burn program to permit the units to stabilize. They were allowed to continue to operate for an extended period of time following the completion of the burn trial. This permitted the evaluation of the performance and responsiveness of the monitors. Data recorded by the AQ501 was in ppm units. Data recorded by the external data logger for the CD-1 was converted to concentration in ppm using conversion factors determined from instrument calibration.

3.0 Results and Discussion

3.1 Particulates

A large amount of data was collected and was summarized for interpretation. The appendix contains summary data on all the filter-collection and electronic particulate (RAM and DataRAM) measurements. Table A-1 contains the TSP or Total Suspended Particulate results, Table A-2 shows the PM-10 results and Table A-3 contains the summary PM-2.5 results. Table A-4 shows the RAM results and Table A-5 summarizes the DataRAM results. Table 2 shows the summary results of all particulate measurements before correction for background levels. Correlation between the different measurement techniques does not appear to be good. Table 3 presents the same summary of all particulate measurements, but corrected for

Table 2 Summary of Particulate Measurements

Burn I.D.	Date	Position	TSP Concentration mg/m³	RAM Concentration mg/m³	DataRAM Concentration mg/m³	PM-10 Concentration mg/m³	DataRAM PM-10 Concentration mg/m³	PM-2.5 Concentration mg/m³	DataRAM PM-2.5 Concentration mg/m³
Background	24-Sep-97	DW1A	0.32	0.06	0.01	0.30		0.00	
Background	24-Sep-97	DW1B	0.58	0.6	0.01	0.26		0.15	
Background	24-Sep-97	DW2B	0.45	0	0.01	0.28		0.06	
Background	24-Sep-97	DW1C	0.38	0.01	0.01	0.25		0.10	
Background	24-Sep-97	UW1B	0.40	0.13	0.01	0.31		0.11	
Boom 2, Burn 1	26-Sep-97	DW1A	0.33	0.24	0.1	0.07		0.25	
Boom 2, Burn 1	26-Sep-97	DW1B	0.51	0.52	0.26	0.42		0.34	
Boom 2, Burn 1	26-Sep-97	DW2B	0.25	0.57	0.16	0.30		0.27	
Boom 2, Burn 1	26-Sep-97	DW1C	0.27	0.17	0.13	0.28		0.77	
Boom 2, Burn 1	26-Sep-97	UW1B	0.18	0.14	0.02	0.15		0.03	
Boom 2, Burn 2	26-Sep-97	DW1A	0.10	0.15	0.02	0.14		0.00	
Boom 2, Burn 2	26-Sep-97	DW1B	0.13	0.21	0.1	0.23		0.07	
Boom 2, Burn 2	26-Sep-97	DW2B	0.12	0.4	0.05			0.01	
Boom 2, Burn 2	26-Sep-97	DW1C	0.11	0.2	0.12			0.15	
Boom 2, Burn 2	26-Sep-97	UW1B	0.06	0.14	0.018	0.17		0.00	
Boom 2, Burn 3	26-Sep-97	DW1A	0.12	0.14	0.05	0.20		0.11	
Boom 2, Burn 3	26-Sep-97	DW1B	0.20	0.27	0.1	0.23		0.08	
Boom 2, Burn 3	26-Sep-97	DW2B	0.20	0.48	0.12	0.24		0.18	
Boom 2, Burn 3	26-Sep-97	DW1C	0.14	0.04	0.04	0.19		0.04	
Boom 2, Burn 3	26-Sep-97	UW1B	0.12	0.15	0.03	0.14		0.00	
Boom 3, Burn 1	29-Sep-97	DW1A	0.52	0.25		0.36	0.10	0.00	
Boom 3, Burn 1	29-Sep-97	DW1B	0.56	0.15		0.41	0.08	0.00	
Boom 3, Burn 1	29-Sep-97	DW2B	0.44	0.04		0.37	0.09	0.00	
Boom 3, Burn 1	29-Sep-97	DW1C	0.45	0		0.37	0.08	0.23	
Boom 3, Burn 1	29-Sep-97	UW1B	0.46	0.29		0.30	0.07	0.17	
Boom 3a, Burn 1	30-Sep-97	DW1A	0.30	0.17		0.12	0.17	0.15	
Boom 3a, Burn 1	30-Sep-97	DW1B		0.2		0.25	0.13	0.07	
Boom 3a, Burn 1	30-Sep-97	DW2B	0.30	0.14		0.14	0.15	0.08	
Boom 3a, Burn 1	30-Sep-97	DW1C	0.27	0.15		0.15	0.14	0.14	
Boom 3a, Burn 1	30-Sep-97	UW1B	0.29	0.13		0.11	0.13	0.15	
Boom 4, Burn 1 + 2	1-Oct-97	DW1A	0.11	0.26		0.17	0.23	0.14	
Boom 4, Burn 1 + 2	1-Oct-97	DW1B	0.18	0.67		0.29	0.64	0.13	
Boom 4, Burn 1 + 2	1-Oct-97	DW2B	0.16	1.56		0.28	0.34	0.16	
Boom 4, Burn 1 + 2	1-Oct-97	DW1C	0.12	1.11		0.07	0.25	0.08	
Boom 4, Burn 1 + 2	1-Oct-97	UW1B	0.00	0.64		0.12	0.17	0.06	
Boom 4, Burn 3	1-Oct-97	DW1A	0.06	0.08		0.12		0.20	0.03
Boom 4, Burn 3	1-Oct-97	DW1B	0.35	0.47		0.43		0.20	0.17
Boom 4, Burn 3	1-Oct-97	DW2B	0.17	0.86		0.22		0.21	0.19
Boom 4, Burn 3	1-Oct-97	DW1C	0.52	0.98		0.81		0.63	0.62
Boom 4, Burn 3	1-Oct-97	UW1B	0.00	0.3		0.05		0.16	0.02
Boom 5, Burn 1	2-Oct-97	DW1A	0.09	0.23		0.15		0.21	0.11
Boom 5, Burn 1	2-Oct-97	DW1B	0.12	0.41		0.23		0.52	0.16
Boom 5, Burn 1	2-Oct-97	DW2B	0.14	0.78		0.20		0.34	0.13
Boom 5, Burn 1	2-Oct-97	DW1C	0.00	0.06		0.03		0.00	0.03
Boom 5, Burn 1	2-Oct-97	UW1B	0.00	0.18		0.00		0.18	0.07

background. The filter measurements (TSP, PM-10 and PM-2.5) were corrected for background by subtracting the upwind measurement and the electronic measurements (RAM and DataRAM) were corrected by subtracting the before-burn values. It is important to recognize that the background readings of the RAM and DataRAM are often very high, as can be seen in Table A-4 and Table A-5, and without correction the readings are meaningless. It was noted that these instruments and the DataRAM especially, were affected by humidity and typically readings decreased throughout the morning as the humidity levels decreased. Background readings, without any smoke particulates being present, were often well above the 150 $\mu g/m^3$ regulatory limits. This is largely the result of sensitivity to water droplets (humidity). It is possible, as seen here, to correct for this to a certain extent by subtracting the before-burning readings or the after-burn readings if these were not consistent with the before-burn values, indicating that the instrument background was decreasing during the burn. The best measure to correct these is to plot the data and then remove the background by a proper slope correction. Obviously, both the RAM and DataRAM, although fully-capable of providing accurate readings, require great expertise in operation and especially in calibration and adjustment of readings. They should not be used as a field instrument without a high level of training in measuring and correcting for background.

The correlation of the various measurements are shown in Table 4 and Table 5. Table 4 shows the correlation, or the lack of it, for uncorrected measurements, while Table 5 shows the correlation between the background-corrected measurements. Two types of correlation are shown in the tables. The first line in a given row shows the r^2, regression coefficient, for the best equation that relates the two sets of data. The relationship of the linear equation (2-parameter, eg. $y = a + bx$) is then given (ie. the 'b' value). If the correlation is high, a single parameter equation can be fitted as shown in the second row of each category (ie. $y = ax$, thus the 'a' is the single-parameter relation). Table 4 shows that the correlation between uncorrected values is generally very poor, however, Table 5 shows that the correlation between background-corrected values is very good. Table 5 can be used to establish relationships between parameters for this burn. This shows that PM-10 values for this type of burn are about the same as the TSP values. Similarly, the PM-2.5 values are also about the same as the TSP values. These show that the TSP, PM-10 and PM-2.5 measurements may overlap with the different instruments detecting the same particle of perhaps a piece of the same particle. One explanation for this is that the soot particle may be fragmented during the measurement. Thus all sampling instruments may read about the same, irrespective of size measurement. Another factor may be that variability in smoke plume distribution and precipitation may show this variability. All of the high-volume samplers were corrected using a single upwind value, thus the data is highly dependant on this being representative.

Three separate means were used to measure TSP, the high-volume sampler which is the approved standard, the RAM and the DataRAM. The latter was used during certain burns only. Table 5 shows that the TSP by the high volume absolute is about half that read by the RAM. This may be a result of low correction of the RAMs or in other words, that all the background was not removed from the RAM data. The DataRAM TSP correlates highly with the high-volume TSP and has about the same

Table 3 **Summary of Particulate Measurements Corrected for Upwind Values or Before Burn Values ***

Burn I.D.	Date	Position	TSP Concentration mg/m³	RAM Concentration mg/m³	DataRAM Concentration mg/m³	PM-10 Concentration mg/m³	DataRAM PM-10 Concentration mg/m³	PM-2.5 Concentration mg/m³	DataRAM PM-2.5 Concentration mg/m³
Background	24-Sep-97	DW1A	0.00	0.00	0.00	0.00		0.00	
Background	24-Sep-97	DW1B	0.18	0.01	0.00	0.00		0.03	
Background	24-Sep-97	DW2B	0.06	0.00	0.00	0.00		0.00	
Background	24-Sep-97	DW1C	0.00	0.00	0.00	0.00		0.00	
Background	24-Sep-97	UW1B	0.00	0.00	0.00	0.00		0.00	
Boom 2, Burn 1	26-Sep-97	DW1A	0.15	0.10	0.08	0.00		0.03	
Boom 2, Burn 1	26-Sep-97	DW1B	0.33	0.43	0.24	0.27		0.11	
Boom 2, Burn 1	26-Sep-97	DW2B	0.07	0.21	0.14	0.15		0.04	
Boom 2, Burn 1	26-Sep-97	DW1C	0.09	0.15	0.11	0.13		0.54	
Boom 2, Burn 1	26-Sep-97	UW1B	0.00	0.00	0.00	0.00		0.00	
Boom 2, Burn 2	26-Sep-97	DW1A	0.04	0.00	0.00	0.00		0.00	
Boom 2, Burn 2	26-Sep-97	DW1B	0.07	0.11	0.09	0.06		0.07	
Boom 2, Burn 2	26-Sep-97	DW2B	0.06	0.04	0.03	0.00		0.01	
Boom 2, Burn 2	26-Sep-97	DW1C	0.04	0.05	0.10	0.00		0.15	
Boom 2, Burn 2	26-Sep-97	UW1B	0.00	0.00	0.00	0.00		0.00	
Boom 2, Burn 3	26-Sep-97	DW1A	0.00	0.02	0.02	0.06		0.11	
Boom 2, Burn 3	26-Sep-97	DW1B	0.08	0.16	0.07	0.08		0.08	
Boom 2, Burn 3	26-Sep-97	DW2B	0.08	0.12	0.10	0.09		0.18	
Boom 2, Burn 3	26-Sep-97	DW1C	0.02	0.02	0.01	0.04		0.04	
Boom 2, Burn 3	26-Sep-97	UW1B	0.00	0.00	0.00	0.00		0.00	
Boom 3, Burn 1	29-Sep-97	DW1A	0.06	0.00		0.06	0.00	0.00	
Boom 3, Burn 1	29-Sep-97	DW1B	0.11	0.00		0.11	0.00	0.00	
Boom 3, Burn 1	29-Sep-97	DW2B	0.00	0.00		0.07	0.00	0.00	
Boom 3, Burn 1	29-Sep-97	DW1C	0.00	0.00		0.07	0.00	0.06	
Boom 3, Burn 1	29-Sep-97	UW1B	0.00	0.00		0.00	0.00	0.00	
Boom 3a, Burn 1	30-Sep-97	DW1A	0.01	0.01		0.01	0.00	0.00	
Boom 3a, Burn 1	30-Sep-97	DW1B	0.00	0.01		0.14	0.00	0.00	
Boom 3a, Burn 1	30-Sep-97	DW2B	0.01	0.05		0.02	0.00	0.00	
Boom 3a, Burn 1	30-Sep-97	DW1C	0.00	0.00		0.04	0.00	0.00	
Boom 3a, Burn 1	30-Sep-97	UW1B	0.00	0.02		0.00	0.00	0.00	
Boom 4, Burn 1 + 2	1-Oct-97	DW1A	0.05	0.02		0.04	0.00	0.08	
Boom 4, Burn 1 + 2	1-Oct-97	DW1B	0.12	0.34		0.17	0.00	0.07	
Boom 4, Burn 1 + 2	1-Oct-97	DW2B	0.10	0.14		0.16	0.00	0.10	
Boom 4, Burn 1 + 2	1-Oct-97	DW1C	0.06	0.09		0.00	0.00	0.02	
Boom 4, Burn 1 + 2	1-Oct-97	UW1B	0.00	0.01		0.00	0.00	0.00	
Boom 4, Burn 3	1-Oct-97	DW1A	0.07	0.00		0.08		0.03	0
Boom 4, Burn 3	1-Oct-97	DW1B	0.35	0.35		0.39		0.03	0.13
Boom 4, Burn 3	1-Oct-97	DW2B	0.17	0.23		0.18		0.05	0.15
Boom 4, Burn 3	1-Oct-97	DW1C	0.53	0.92		0.77		0.47	0.58
Boom 4, Burn 3	1-Oct-97	UW1B	0.00	0.00		0.00		0.00	0
Boom 5, Burn 1	2-Oct-97	DW1A	0.09	0.11		0.15		0.03	0.1
Boom 5, Burn 1	2-Oct-97	DW1B	0.12	0.33		0.23		0.35	0.15
Boom 5, Burn 1	2-Oct-97	DW2B	0.14	0.16		0.20		0.16	0.12
Boom 5, Burn 1	2-Oct-97	DW1C	0.00	0.03		0.03		0.00	0.02
Boom 5, Burn 1	2-Oct-97	UW1B	0.00	0.00		0.00		0.00	0

* values for the filter samplers (TSP, PM-10 and PM-2.5 were corrected by the upwind data values for the electronic meters, Ram and Dataram, were corrected by values before the burns

Table 4 **Correlation of particulates by type and measurement**

	RAM-I- TSP		DataRAM-TSP		PM-10		DataRAM-PM10		PM-2.5		DataRAM - PM 2.5	
	r^2	Relation	r^2	Relation	r^2	Relation	r^2	Relation	r^2	Relation	r^2	Relation
TSP *	0.08	-0.03	0.4	0.23	0.56	0.84	0.75	-0.62	-0	0.14	0.84	0.87
single-parameter equation					0.47	1.01					0.82	0.91
RAM-I- TSP					0.09	0.58	0.52	1.73	0.13	0.6	0.69	1.45
single-parameter equation							0.32	1.95			0.33	2.09
DataRAM-TSP					0.49	0.38			0.59	0.37		
single-parameter equation					0.19	0.3			0.16	0.33		
PM-10							0.44	-0.1	0.16	0.32	0.9	1.3
single-parameter equation											0.88	1.38
DataRAM-PM10									0.12	0.37		
single-parameter equation												
PM-2.5											0.65	0.84
single-parameter equation											0.3	1.24

** the first line in each row contains the r^2 for the best equation and the relationship from a standard straight line equation*
the second row, the r^2 from a single-parameter linear equation

Table 5 **Correlation of Particulates by type and measurement**
Particulate Data Corrected for Background Levels

	RAM-I- TSP		DataRAM-TSP		PM-10		DataRAM-PM10		PM-2.5		DataRAM - PM 2.5	
	r^2	Relation	r^2	Relation	r^2	Relation	r^2	Relation	r^2	Relation	r^2	Relation
TSP *	0.83	0.56	0.83	1.07	0.81	0.69	*data set*		0.44	0.69	0.78	0.84
single-parameter equation	0.8	0.61	0.69	1.06	0.79	0.73	*are all zeroes*		0.26	0.9	0.72	1
RAM-I- TSP			0.93	1.59	0.86	1.16	*after*		0.66	1.4	0.96	1.59
single-parameter equation			0.89	1.51	0.86	1.14	*correction*		0.56	1.54	0.95	1.64
DataRAM-TSP					0.77	0.77	*for background*		0.25	0.48		
single-parameter equation					0.7	0.9						
PM-10									0.67	1.04	0.9	1.23
single-parameter equation									0.46	1.25	0.85	1.41
DataRAM-PM10	*data set are all zeroes after correction for background*											
single-parameter equation												
PM-2.5											0.68	0.8
single-parameter equation											0.68	0.84

** the first line in each row contains the r^2 for the best equation and the relationship from a standard straight line equation*
the second row, the r^2 from a single-parameter linear equation

level of values. The DataRAM was also used to measure PM-10s and PM-2.5s. In the case of the PM-10s, all values were zero after background correction. In the case of the PM-2.5, the correlation was moderate and the values of the DataRAM PM-2.5 measurements were higher than the absolute PM-2.5 measurements. Considering the high variability in these experiments, overall there was excellent agreement between the high-volume samplers and good agreement between the RAM, DataRAM and the high-volume samplers.

The spatial aspects of the soot distribution were examined and this shows that as expected, that the downwind concentrations are highest at the closest measuring point directly downwind. Because of the variability of the winds in these trials, several sample stations recovered soot. The distribution of soot for the burn for testing boom 2, test 1, is shown in Figure 2. This shows the expected 'hump' along the most frequent wind direction and the expected square-root decline in soot concentrations. Figure 3 shows the aggregate of several burns in which the wind varied. This figure shows a simple decline in soot concentration with distance with little influence of the angle, as would be expected with several wind directions.

3.2 Carbon Dioxide

As for the particulates, extensive data were collected and summary data are presented in Tables A-6 and A-7 in the Appendix. Values in the tables and in discussion here are above the typical background of 300 ppm. Because of the small size of the fire, there is only a low concentration of carbon dioxide, especially in comparison to the 1994 trials (Fingas *et al.* 1996). The ground concentration is generally between 0 and 40 ppm above the approximately 300 ppm background. The burn area in this trial was about 5 m^2 whereas the burn area in the 1994 trials was about 230 m^2. During the 1994 trials about 50 to 200 ppm carbon dioxide was measured. These data indicate a consistency in measured CO_2 compared to the size of the burn.

Table 6 shows a small summary set of data. This shows that the average concentration is either the greatest at the 4 metre measurement point or at the 0.5 measurement point. Comparison of this data with the wind data appears to indicate that the concentration is greatest at the 0.5 level when the wind is blowing directly at the stations and is the greatest at the 4-metre point when the wind is highly variable or blowing at an angle from the measurement stations. The data appear to form a consistent set, however, aside from this behaviour. Figure 4 shows the three-dimensional distribution of the carbon dioxide when all the data from Table 6 are included. This shows that there is structure to the carbon dioxide distributions. It should be noted that the carbon dioxide distribution is complicated by the fact that the concentrations near to the fire are lower than those at about 30 m. This is probably a result of the fact that the source of the carbon dioxide derives from slumping out of the plume. This does not occur instantly, thus maximum concentrations are found some metres from the fire. This has been noted before, the maximum concentration was also found at 30 to 50 metres in the 1994 burn trials (Fingas *et al.* 1996). Figure 5 shows the three-dimension view of the Carbon Dioxide concentrations from those burns where the wind varied or the smoke plume was not directly overhead the measurement instruments.

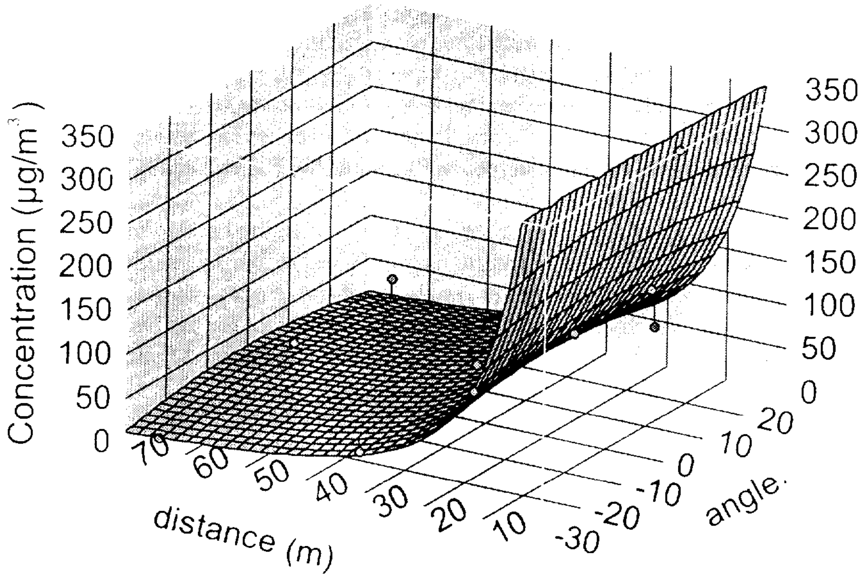

Figure 2 Curve Fit of Boom 2 -Burn 1 - Soot Spatial Distribution

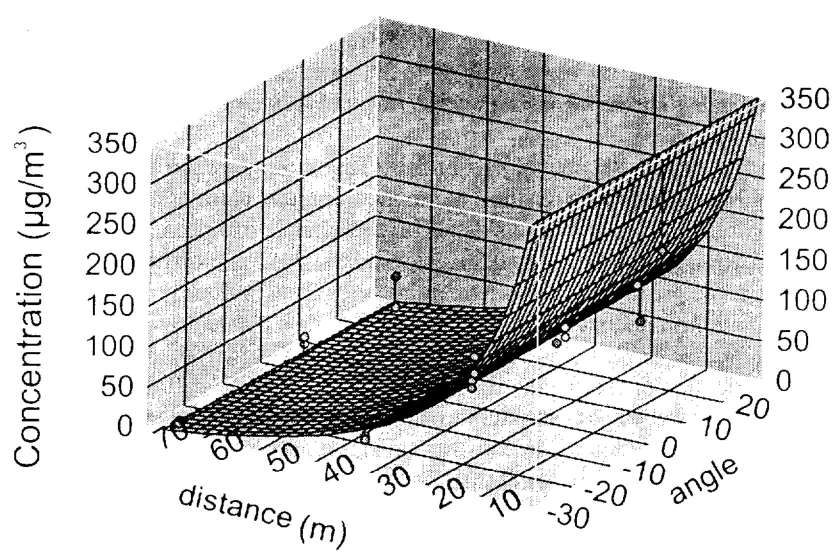

Figure 3 Curve Fit of Several Burns - Soot Spatial Distribution

Table 6 **Summary of Carbon Dioxide Measurements**

Burn	Carbon Dioxide Concentration at Measurement Height (ppm) 0.5 m	1 m	2 m	4 m	distance (m)
Burn 2-1	35	21	17	34	15
Burn 2-2	40	21	22	40	15
Burn 2-3	28	21	16	35	15
Burn 5-1	32	17	4	55	15
Burn 2-1	3	5	28	17	30
Burn 3-1	19	21		140	30
Burn 3a-1	50	56	67	174	30
Burn 4-1	9	19		95	30
Burn 4-3	4	2		77	30
Burn 5-1	8	1		44	30
Burn 2-1	29	19	18	20	72
Burn 2-2	21	11	2	6	72
Burn 2-3	32	1	17	9	72

The carbon dioxide concentrations around the burn are again much more evenly distributed than the soot concentrations as has also been found in previous burns. Especially when the wind has a low velocity, usually under about 5 m/s, the carbon dioxide is distributed all around the burn. As the wind velocity increases, it is increasingly distributed along the wind direction.

4.0 Summary and Conclusions

4.1 Particulates

The diesel burns produced an abundance of particulate matter. This particulate matter was distributed decreasingly with distance downwind from the fire. Concentrations at ground level (1 m) were above normal occupational health limits (150 $\mu g/m^3$) only as far downwind as 30 to 50 m. This is related to burn area, which in this case was very small (~5 m^2). A typical contained fire would have an area 10 to 100 times this size. It was found that the concentrations of TSP, PM-10 and PM-2.5 were about the same at the 6 sites where precision instruments were co-located. This may be indicative that the soot particle is broken down by the measurement devices.

The various instruments used to measure particulates yielded about the same values at the same locations for the same burns. The electronic measuring instruments, the RAM and DataRAM, however required a full background correction with data from before and after the burn. The background levels in these instruments was strongly affected by moisture in the air. It was found that background levels could exceed actual measurements by as much as five and could be over the occupational health limit by as much, without measuring burn particulate matter. After correction, the correlation of the RAM and DataRAM data with that of the precision instruments was good, except that the DataRAM showed poor correlation in measuring PM-10 and to a lesser extent PM-2.5.

The downwind distribution of soot could be characterized by simple mathematical functions.

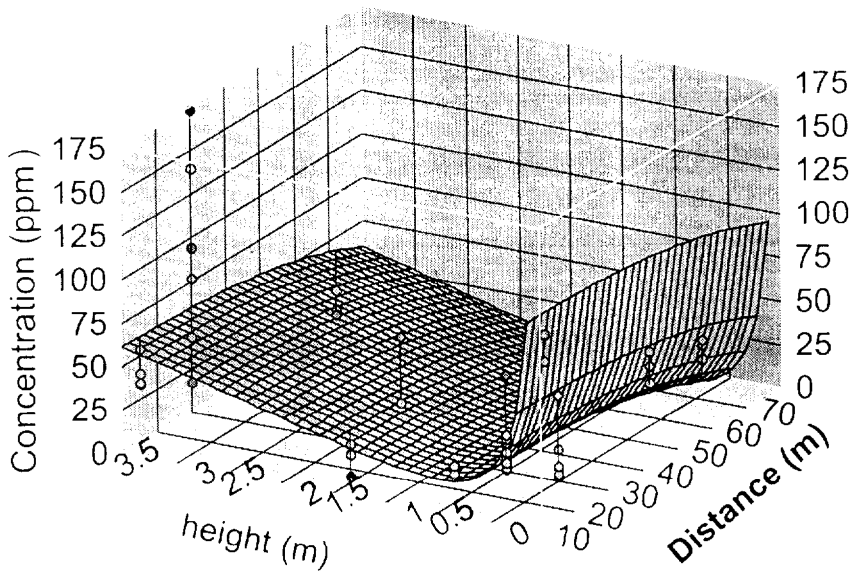

Figure 4 Three-Dimensional View of Carbon Dioxide Distribution - Sum of All Burn Data

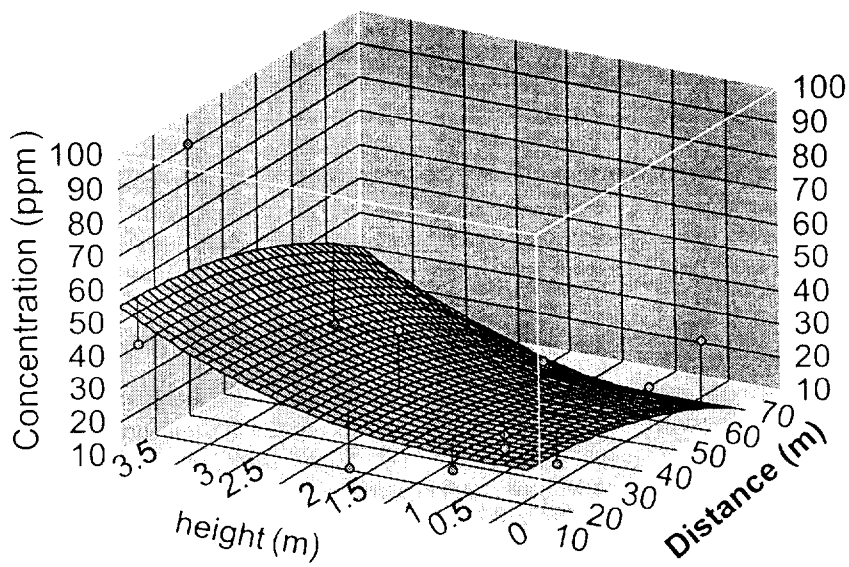

Figure 5 Three-Dimensional View of Carbon Dioxide Distribution - Data Where Wind Varied

4.2 Carbon Dioxide

An extensive array of instruments was used to characterize the 3-dimensional distribution of carbon dioxide. Concentrations of carbon dioxide are highest at the 0.5 m level under most conditions. Concentrations were highest at the 4 m level when winds were not directly overhead the measuring instruments. Concentrations are distributed downwards away from the fire. Distribution along the ground is broader than for particulates.

5.0 References

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Table A-1 Total Suspended Particulate Results

Burn Description	Date	Position	Air Volume m^3	TSP Concentration mg/m^3
Background	24-Sep-97	DW1A	99.93	0.32
Background	24-Sep-97	DW1B	89.15	0.58
Background	24-Sep-97	DW2B	104.46	0.45
Background	24-Sep-97	DW1C	87.98	0.38
Background	24-Sep-97	UW1B	96.76	0.40
Boom 2, Burn 1	26-Sep-97	DW1A	108.18	0.33
Boom 2, Burn 1	26-Sep-97	DW1B	95.47	0.51
Boom 2, Burn 1	26-Sep-97	DW2B	123.38	0.25
Boom 2, Burn 1	26-Sep-97	DW1C	93.6	0.27
Boom 2, Burn 1	26-Sep-97	UW1B	104.04	0.18
Boom 2, Burn 2	26-Sep-97	DW1A	116.65	0.10
Boom 2, Burn 2	26-Sep-97	DW1B	105.9	0.13
Boom 2, Burn 2	26-Sep-97	DW2B	115.28	0.12
Boom 2, Burn 2	26-Sep-97	DW1C	106.31	0.11
Boom 2, Burn 2	26-Sep-97	UW1B	97.1	0.06
Boom 2, Burn 3	26-Sep-97	DW1A	107.29	0.12
Boom 2, Burn 3	26-Sep-97	DW1B	95.92	0.20
Boom 2, Burn 3	26-Sep-97	DW2B	106.86	0.20
Boom 2, Burn 3	26-Sep-97	DW1C	99.08	0.14
Boom 2, Burn 3	26-Sep-97	UW1B	98.13	0.12
Boom 3, Burn 1	29-Sep-97	DW1A	71.67	0.52
Boom 3, Burn 1	29-Sep-97	DW1B	55.85	0.56
Boom 3, Burn 1	29-Sep-97	DW2B	66.99	0.44
Boom 3, Burn 1	29-Sep-97	DW1C	61.62	0.45
Boom 3, Burn 1	29-Sep-97	UW1B	63.34	0.46
Boom 3a, Burn 1	30-Sep-97	DW1A	233.96	0.30
Boom 3a, Burn 1	30-Sep-97	DW2B	226.39	0.30
Boom 3a, Burn 1	30-Sep-97	DW1C	204.69	0.27
Boom 3a, Burn 1	30-Sep-97	UW1B	222.73	0.29
Boom 4, Burn 1 + 2	1-Oct-97	DW1A	224.9	0.11
Boom 4, Burn 1 + 2	1-Oct-97	DW1B	208.27	0.18
Boom 4, Burn 1 + 2	1-Oct-97	DW2B	230.39	0.16
Boom 4, Burn 1 + 2	1-Oct-97	DW1C	190.33	0.12
Boom 4, Burn 3	1-Oct-97	DW1A	109.75	0.06
Boom 4, Burn 3	1-Oct-97	DW1B	97.47	0.35
Boom 4, Burn 3	1-Oct-97	DW2B	102.53	0.17
Boom 4, Burn 3	1-Oct-97	DW1C	92.81	0.52
Boom 4, Burn 3	1-Oct-97	UW1B	101.59	0.00
Boom 5, Burn 1	2-Oct-97	DW1A	109.33	0.09
Boom 5, Burn 1	2-Oct-97	DW1B	103.23	0.12
Boom 5, Burn 1	2-Oct-97	DW2B	109.95	0.14
Boom 5, Burn 1	2-Oct-97	DW1C	97.16	-0.14
Boom 5, Burn 1	2-Oct-97	UW1B	104.76	-0.11

Table A-2 **PM-10 Summary Results**

Burn Description	Date	Position	Air Volume m^3	PM-10 Concentration mg/m^3
Background	24-Sep-97	DW1A	87.38	0.30
Background	24-Sep-97	DW1B	79.07	0.26
Background	24-Sep-97	DW2B	90.50	0.28
Background	24-Sep-97	DW1C	71.56	0.25
Background	24-Sep-97	UW1B	87.61	0.31
Boom 2, Burn 1	26-Sep-97	DW1A	94.54	0.07
Boom 2, Burn 1	26-Sep-97	DW1B	90.16	0.42
Boom 2, Burn 1	26-Sep-97	DW2B	88.96	0.30
Boom 2, Burn 1	26-Sep-97	DW1C	79.67	0.28
Boom 2, Burn 1	26-Sep-97	UW1B	94.80	0.15
Boom 2, Burn 2	26-Sep-97	DW1A	92.67	0.14
Boom 2, Burn 2	26-Sep-97	DW1B	83.67	0.23
Boom 2, Burn 2	26-Sep-97	UW1B	92.95	0.17
Boom 2, Burn 3	26-Sep-97	DW1A	86.99	0.20
Boom 2, Burn 3	26-Sep-97	DW1B	104.32	0.23
Boom 2, Burn 3	26-Sep-97	DW2B	94.49	0.24
Boom 2, Burn 3	26-Sep-97	DW1C	75.34	0.19
Boom 2, Burn 3	26-Sep-97	UW1B	87.25	0.14
Boom 3, Burn 1	29-Sep-97	DW1A	57.21	0.36
Boom 3, Burn 1	29-Sep-97	DW1B	53.24	0.41
Boom 3, Burn 1	29-Sep-97	DW2B	59.37	0.37
Boom 3, Burn 1	29-Sep-97	DW1C	52.38	0.37
Boom 3, Burn 1	29-Sep-97	UW1B	57.33	0.30
Boom 3a, Burn 1	30-Sep-97	DW1A	197.49	0.12
Boom 3a, Burn 1	30-Sep-97	DW1B	164.80	0.25
Boom 3a, Burn 1	30-Sep-97	DW2B	205.22	0.14
Boom 3a, Burn 1	30-Sep-97	DW1C	171.75	0.15
Boom 3a, Burn 1	30-Sep-97	UW1B	195.84	0.11
Boom 4, Burn 1 + 2	1-Oct-97	DW1A	188.90	0.17
Boom 4, Burn 1 + 2	1-Oct-97	DW1B	180.09	0.29
Boom 4, Burn 1 + 2	1-Oct-97	DW2B	177.68	0.28
Boom 4, Burn 1 + 2	1-Oct-97	DW1C	168.17	0.07
Boom 4, Burn 1 + 2	1-Oct-97	UW1B	183.64	0.12
Boom 4, Burn 3	1-Oct-97	DW1A	91.73	0.12
Boom 4, Burn 3	1-Oct-97	DW1B	87.19	0.43
Boom 4, Burn 3	1-Oct-97	DW2B	88.69	0.22
Boom 4, Burn 3	1-Oct-97	DW1C	74.72	0.81
Boom 4, Burn 3	1-Oct-97	UW1B	75.88	0.05
Boom 5, Burn 1	2-Oct-97	DW1A	91.99	0.15
Boom 5, Burn 1	2-Oct-97	DW1B	87.85	0.23
Boom 5, Burn 1	2-Oct-97	DW2B	91.05	0.20
Boom 5, Burn 1	2-Oct-97	DW1C	79.87	0.03
Boom 5, Burn 1	2-Oct-97	UW1B	90.34	-0.01

Table A-3 PM-2.5 Summary Results

Burn Description	Date	Position	Air Volume m^3	PM-2.5 Concentration mg/m^3
Background	24-Sep-97	DW1 A	1.00	-0.02
Background	24-Sep-97	DW1 B	1.00	1.45
Background	24-Sep-97	DW1 C	1.00	0.10
Background	24-Sep-97	DW2 B	1.00	0.06
Background	24-Sep-97	UW1 B	1.00	0.11
Boom 2, Burn 1	26-Sep-97	DW1 A	1.10	0.25
Boom 2, Burn 1	26-Sep-97	DW1 B	1.10	0.34
Boom 2, Burn 1	26-Sep-97	DW1 C	1.00	0.77
Boom 2, Burn 1	26-Sep-97	DW2 B	1.00	0.27
Boom 2, Burn 1	26-Sep-97	UW1 B	1.10	0.03
Boom 2, Burn 2	26-Sep-97	DW1 A	1.00	-0.02
Boom 2, Burn 2	26-Sep-97	DW1 B	1.10	0.07
Boom 2, Burn 2	26-Sep-97	DW1 C	1.00	0.15
Boom 2, Burn 2	26-Sep-97	DW2 B	1.10	0.01
Boom 2, Burn 2	26-Sep-97	UW1 B	1.10	-0.03
Boom 2, Burn 3	26-Sep-97	DW1 A	1.10	0.11
Boom 2, Burn 3	26-Sep-97	DW1 B	1.10	0.08
Boom 2, Burn 3	26-Sep-97	DW1 C	1.00	0.04
Boom 2, Burn 3	26-Sep-97	DW2 B	1.10	0.18
Boom 2, Burn 3	26-Sep-97	UW1 B	1.00	-0.27
Boom 3, Burn 1	29-Sep-97	DW1 A	0.40	-0.04
Boom 3, Burn 1	29-Sep-97	DW1 B	0.60	-0.45
Boom 3, Burn 1	29-Sep-97	DW1 C	0.60	0.23
Boom 3, Burn 1	29-Sep-97	DW2 B	0.60	-0.25
Boom 3, Burn 1	29-Sep-97	UW1 B	0.70	0.17
Boom 3a, Burn 1	29-Sep-97	DW1 A	2.20	0.15
Boom 3a, Burn 1	29-Sep-97	DW1 B	2.20	0.07
Boom 3a, Burn 1	29-Sep-97	DW1 C	2.20	0.08
Boom 3a, Burn 1	29-Sep-97	DW2 B	1.10	0.14
Boom 3a, Burn 1	29-Sep-97	UW1 B	2.20	0.15
Boom 4, Burn 1 + 2	1-Oct-97	DW1 A	2.10	0.14
Boom 4, Burn 1 + 2	1-Oct-97	DW1 B	2.10	0.13
Boom 4, Burn 1 + 2	1-Oct-97	DW1 C	2.10	0.08
Boom 4, Burn 1 + 2	1-Oct-97	DW2 B	2.10	0.16
Boom 4, Burn 1 + 2	1-Oct-97	UW1 B	2.10	0.06
Boom 4, Burn 3	1-Oct-97	DW1 A	1.00	0.20
Boom 4, Burn 3	1-Oct-97	DW1 B	1.10	0.20
Boom 4, Burn 3	1-Oct-97	DW1 C	1.10	0.63
Boom 4, Burn 3	1-Oct-97	DW2 B	1.10	0.21
Boom 4, Burn 3	1-Oct-97	UW1 B	1.10	0.16
Boom 5, Burn 1	2-Oct-97	DW1 A	1.00	0.21
Boom 5, Burn 1	2-Oct-97	DW1 B	1.00	0.52
Boom 5, Burn 1	2-Oct-97	DW1 C	1.00	0.00
Boom 5, Burn 1	2-Oct-97	DW2 B	1.00	0.34
Boom 5, Burn 1	2-Oct-97	UW1 B	1.00	0.18

Table A-4a **Summary Table of RAM-I Results**

Total Aerosol Monitored by the RAM-1 (µg/m³)

Background

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2A 27°, 45 m 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 m 1 m
Pre-Burn 30 min	Average	62.5	604.0	13.7	153.3	0.0	3.7
Burn	Average	60.8	607.7	12.2	152.9	0.0	1.3
	µg/m³ above Pre-Burn	-1.6	3.7	-1.5	-0.4	0.0	-2.4
Post-Burn 15 min	Average	64.2	635.6	12.1	142.2	0.0	0.0
	µg/m³ above Pre-Burn	1.7	31.6	-1.6	-11.1	0.0	-3.7

		DW3A 28°, 75 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3C -29°, 75 m 1 m	DW4B 4°, 75 m 1 m	UW1B 171°, 72 m 1 m
Pre-Burn 30 min	Average	136.0	0.0	10.0	16.3	199.0	17.4	131.0
Burn	Average	135.7	0.0	10.0	15.8	202.2	13.3	128.5
	µg/m³ above Pre-Burn	-0.2	0.0	0.0	-0.5	3.2	-4.1	-2.5
Post-Burn 15 min	Average	129.5	0.0	10.0	15.9	204.6	6.0	127.1
	µg/m³ above Pre-Burn	-6.4	0.0	0.0	-0.3	5.5	-11.4	-3.9

Boom 1, Burn 3

		S3A 54°, 42 m 1 m	S3A 54°, 42 m 1 m	S3A 54°, 42 m 1 m
Pre-Burn 30 min	Average	44.9	0.0	0.0
Burn	Average	67.8	27.0	23.3
	µg/m³ above Pre-Burn	22.9	27.0	23.3
Post-Burn 15 min	Average	48.2	3.0	0.5
	µg/m³ above Pre-Burn	3.3	3.0	0.5

Boom 2, Burn 1

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2A 27°, 45 m 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 m 1 m
Pre-Burn 30 min	Average	139.5	95.8	17.4	0.0	358.2	1.2
Burn	Average	238.4	522.4	170.5	73.8	569.2	52.8
	µg/m³ above Pre-Burn	98.9	426.6	153.1	73.8	211.0	51.6
Post-Burn 15 min	Average	205.5	273.7	100.5	20.5	434.8	58.0
	µg/m³ above Pre-Burn	66.1	177.9	83.1	20.5	76.6	56.7

		DW3A 28°, 75 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3C -29°, 75 m 1 m	DW4B 4°, 75 m 1 m	UW1B 171°, 72 m 1 m
Pre-Burn 30 min	Average	84.7	0.0	14.0	23.0	140.5	0.0	140.3
Burn	Average	124.4	46.9	13.7	23.0	149.7	28.8	135.9
	µg/m³ above Pre-Burn	39.7	46.9	-0.2	-0.1	9.3	28.8	-4.4
Post-Burn 15 min	Average	109.5	0.0	14.1	23.0	159.3	0.0	135.7
	µg/m³ above Pre-Burn	24.9	0.0	0.1	-0.1	18.9	0.0	-4.7

Boom 2, Burn 2

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2A 27°, 45 m 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 m 1 m
Pre-Burn 30 min	Average	144.0	97.8	22.7	0.0	360.3	1.5
Burn	Average	150.4	211.5	196.7	0.0	399.5	51.2
	µg/m³ above Pre-Burn	6.4	113.7	174.0	0.0	39.2	49.7
Post-Burn 15 min	Average	169.8	349.3	377.0	4.7	484.3	212.6
	µg/m³ above Pre-Burn	25.9	251.5	354.2	4.7	124.1	211.1

		DW3A 28°, 75 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3C -29°, 75 m 1 m	DW4B 4°, 75 m 1 m	UW1B 171°, 72 m 1 m
Pre-Burn 30 min	Average	81.1	0.0	13.7	23.1	139.2	0.0	135.8
Burn	Average	95.5	16.4	13.9	23.0	166.3	12.8	136.7
	µg/m³ above Pre-Burn	14.4	16.4	0.2	0.0	27.1	12.8	0.8
Post-Burn 15 min	Average	95.4	0.0	13.9	22.8	202.1	0.0	141.9
	µg/m³ above Pre-Burn	14.3	0.0	0.2	-0.3	63.0	0.0	6.0

Table A-4b **Summary Table of RAM-I Results**

Total Aerosol Monitored by the RAM-1 (µg/m³)

Boom 2, Burn 3

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2A 27°, 45 m 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 m 1 m	
Pre-Burn 30 min	Average	120.2	108.8	22.8	0.0	360.2	12.0	
Burn	Average	139.8	270.5	36.4	21.6	481.2	22.8	
	µg/m³ above Pre-Burn	19.6	161.7	13.6	21.6	121.0	10.8	
Post-Burn 15 min	Average	127.7	588.7	302.8	2.1	649.0	78.3	
	µg/m³ above Pre-Burn	7.5	479.9	280.0	2.1	288.8	66.4	
		DW3A 28°, 75 m 1 m	**DW3B 5°, 45 m 1 m**	**DW3B 5°, 45 m 1 m**	**DW3B 5°, 45 m 1 m**	**DW3C -29°, 75 m 1 m**	**DW4B 4°, 75 m 1 m**	**UW1B 171°, 72 m 1 m**
Pre-Burn 30 min	Average	137.0	0.0	13.6	22.8	163.9	0.0	145.0
Burn	Average	161.2	37.0	13.7	22.7	193.5	30.4	152.9
	µg/m³ above Pre-Burn	24.2	37.0	0.1	-0.2	29.6	30.4	7.9
Post-Burn 15 min	Average	143.2	21.6	14.0	22.6	227.7	9.3	162.0
	µg/m³ above Pre-Burn	6.2	21.6	0.4	-0.2	63.8	9.3	17.0

Boom 3, Burn 1

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2A 27°, 45 m 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 m 1 m	
Pre-Burn 30 min	Average	252.5	167.9	0.0	14.1	43.8	0.0	
Burn	Average	245.0	152.5	0.0	14.0	41.5	0.0	
	µg/m³ above Pre-Burn	-7.5	-15.4	0.0	-0.1	-2.3	0.0	
Post-Burn 15 min	Average	328.2	211.6	0.0	14.0	40.4	0.0	
	µg/m³ above Pre-Burn	75.7	43.7	0.0	-0.1	-3.4	0.0	
		DW3A 28°, 75 m 1 m	**DW3B 5°, 45 m 1 m**	**DW3B 5°, 45 m 1 m**	**DW3B 5°, 45 m 1 m**	**DW3C -29°, 75 m 1 m**	**DW4B 4°, 75 m 1 m**	**UW1B 171°, 72 m 1 m**
Pre-Burn 30 min	Average	321.4	261.6	10.0	16.4	3218.2	122.0	336.9
Burn	Average	302.4	210.3	10.0	16.4	3156.3	126.6	312.0
	µg/m³ above Pre-Burn	-18.9	-51.3	0.0	0.0	-61.9	4.6	-24.8
Post-Burn 15 min	Average	305.5	166.8	10.0	16.4	3184.7	128.3	294.4
	µg/m³ above Pre-Burn	-15.9	-94.7	0.0	0.0	-33.5	6.3	-42.4

Boom 3a, Burn 1

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2A 27°, 45 m 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 m 1 m	
Pre-Burn 30 min	Average	*	*	*	*	*	*	
Burn	Average	167.0	204.1	150.9	85.4	144.0	143.7	
	µg/m³ above Post-Burn	6.6	11.3	0.8	25.5	47.9	2.4	
Post-Burn 15 min	Average	160.4	192.8	150.1	59.9	96.1	141.3	

* the Pre-Burn period is very noisy, the above difference of this data set is calculated on 15 minutes of Post-Burn

		DW3A 28°, 75 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3C -29°, 75 m 1 m	DW4B 4°, 75 m 1 m	UW1B 171°, 72 m 1 m
Pre-Burn 30 min	Average	*	*	*	*	*	*	*
Burn	Average	290.7	171.5	530.4	134.0	203.4	161.9	348.2
	µg/m³ above Post-Burn	6.2	26.8	351.5	-84.3	3.3	16.5	22.9
Post-Burn 15 min	Average	284.4	144.7	179.0	218.3	200.1	145.4	325.3

* the Pre-Burn period is very noisy, the above difference of this data set is calculated on 15 minutes of Post-Burn

Boom 4, Burn 1

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2A 27°, 45 m 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 m 1 m	
Pre-Burn 30 min	Average	138.7	213.9	138.6	137.5	706.6	160.8	
Burn	Average	149.5	204.4	134.8	134.9	702.1	159.7	
	µg/m³ above Pre-Burn	10.8	-9.6	-3.9	-2.5	-4.5	-1.1	
Post-Burn 15 min	Average	123.0	254.8	221.1	93.0	703.1	188.2	
	µg/m³ above Pre-Burn	-15.7	40.9	82.5	-44.5	-3.6	27.4	
		DW3A 28°, 75 m 1 m	**DW3B 5°, 45 m 1 m**	**DW3B 5°, 45 m 1 m**	**DW3B 5°, 45 m 1 m**	**DW3C -29°, 75 m 1 m**	**DW4B 4°, 75 m 1 m**	**UW1B 171°, 72 m 1 m**
Pre-Burn 30 min	Average	329.5	0.0	201.7	195.6	210.1	0.0	322.5
Burn	Average	330.4	0.0	196.1	188.2	208.9	0.0	337.1
	µg/m³ above Pre-Burn	0.9	0.0	-5.6	-7.3	-1.1	0.0	14.6
Post-Burn 15 min	Average	281.3	0.0	169.8	155.8	209.9	0.0	366.0
	µg/m³ above Pre-Burn	-48.1	0.0	-31.9	-39.8	-0.2	0.0	43.4

Table A-4c Summary Table of RAM-I Results

Total Aerosol Monitored by the RAM-1 ($\mu g/m^3$)

Boom 4, Burn 2

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2A 27°, 45 m 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 m 1 m
Pre-Burn 30 min	Average	100.9	144.1	78.7	61.9	656.5	85.7
Burn	Average	110.9	471.9	169.9	62.3	804.7	105.9
	$\mu g/m^3$ above Pre-Burn	10.0	327.8	91.2	0.4	148.1	20.2
Post-Burn 15 min	Average	109.3	386.4	329.0	52.4	777.7	177.7
	$\mu g/m^3$ above Pre-Burn	8.4	242.4	250.3	-9.5	121.2	92.0

		DW3A 28°, 75 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3C -29°, 75 m 1 m	DW4B 4°, 75 m 1 m	UW1B 171°, 72 m 1 m
Pre-Burn 30 min	Average	241.0	0.0	129.3	110.9	156.0	0.0	360.2
Burn	Average	235.9	0.0	249.4	253.0	201.2	18.5	360.8
	$\mu g/m^3$ above Pre-Burn	-5.1	0.0	120.1	142.1	45.2	18.5	0.6
Post-Burn 15 min	Average	230.3	0.0	226.5	229.4	193.8	0.0	330.2
	$\mu g/m^3$ above Pre-Burn	-10.7	0.0	97.1	118.5	37.9	0.0	-30.0

Boom 4, Burn 3

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2A 27°, 45 m 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 m 1 m
Pre-Burn 30 min	Average	88.3	113.4	60.8	31.5	637.4	49.7
Burn	Average	78.5	467.1	981.1	22.9	862.6	567.6
	$\mu g/m^3$ above Pre-Burn	-9.8	353.6	920.2	-8.5	225.2	517.9
Post-Burn 15 min	Average	85.8	109.6	783.6	27.9	630.9	630.2
	$\mu g/m^3$ above Pre-Burn	-2.5	-3.8	722.8	-3.6	-6.5	580.5

		DW3A 28°, 75 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3C -29°, 75 m 1 m	DW4B 4°, 75 m 1 m	UW1B 171°, 72 m 1 m
Pre-Burn 30 min	Average	212.2	0.0	97.3	76.5	152.0	0.0	312.4
Burn	Average	192.7	0.8	311.9	328.8	297.3	10.4	301.2
	$\mu g/m^3$ above Pre-Burn	-19.5	0.8	214.7	252.4	145.3	10.4	-11.2
Post-Burn 15 min	Average	200.9	0.0	91.6	71.6	378.2	0.0	310.4
	$\mu g/m^3$ above Pre-Burn	-11.3	0.0	-5.6	-4.9	226.2	0.0	-2.0

Boom 5, Burn 1

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2A 27°, 45 m 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 m 1 m
Pre-Burn 30 min	Average	113.8	82.2	27.9	0.0	621.5	14.4
Burn	Average	226.1	409.8	56.4	77.3	778.5	40.8
	$\mu g/m^3$ above Pre-Burn	112.3	327.6	28.5	77.3	157.0	26.5
Post-Burn 15 min	Average	141.4	191.3	48.7	14.8	691.3	34.2
	$\mu g/m^3$ above Pre-Burn	27.5	109.1	20.8	14.8	69.8	19.8

		DW3A 28°, 75 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW3C -29°, 75 m 1 m	DW4B 4°, 75 m 1 m	UW1B 171°, 72 m 1 m
Pre-Burn 30 min	Average	48.2	0.0	52.1	36.5	131.8	0.0	172.6
Burn	Average	120.3	11.6	195.5	193.0	141.7	7.1	177.7
	$\mu g/m^3$ above Pre-Burn	72.1	11.6	143.5	156.5	9.9	7.1	5.0
Post-Burn 15 min	Average	157.5	0.0	137.1	139.4	137.6	0.0	177.2
	$\mu g/m^3$ above Pre-Burn	109.2	0.0	85.0	102.9	5.8	0.0	4.5

Table A-5a **Results of the DataRam Monitoring**

Total Aerosol Monitored by the DataRam (µg/m³)

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW4B 4°, 75 m 1 m	UW1B 171°, 72 m 1 m
Background									
Pre-background (30min)	Average	10.9	10.9	10.7	10.0	8.6	9.5	5.7	8.7
Background	Average	9.9	9.7	10.0	8.8	7.3	9.0	5.4	8.6
	µg/m³ above Pre-Background	-1.0	-1.2	-0.7	-1.2	-1.3	-0.5	-0.3	-0.1
Post-background (15 min)	Average	9.3	9.8	10.3	8.7	5.6	8.3	4.4	7.4
	µg/m³ above Pre-Background	-1.5	-1.1	-0.5	-1.3	-3.0	-1.2	-1.3	-1.3
Boom 1, Burn 1									
Pre-Burn 30 min	Average	90.8	80.4	101.6	90.2	88.3	90.1	84.9	90.2
Burn	Average	83.1	79.9	104.3	80.9	90.4	82.6	74.8	79.9
	µg/m³ above Pre-Background	-7.7	-0.6	2.7	-9.3	2.1	-7.5	-10.1	-10.4
Post-Burn 15 min	Average	81.4	97.1	79.6	86.1	81.8	79.1	71.5	74.6
	µg/m³ above Pre-Background	-9.4	16.7	-22.0	-4.2	-6.6	-11.0	-13.4	-15.7
Boom 2, Burn 1									
Pre-Burn 30 min	Average	20.8	19.1	22.0	20.0	20.0	19.8	17.9	18.1
Burn	Average	102.3	263.0	132.9	164.0	110.4	169.0	110.0	16.9
	µg/m³ above Pre-Background	81.6	243.8	110.9	144.0	90.3	149.3	92.1	-1.2
Post-Burn 15 min	Average	34.2	47.2	27.3	57.5	28.5	41.2	43.4	17.9
	µg/m³ above Pre-Background	13.4	28.1	5.3	37.4	8.5	21.4	25.5	-0.2

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 m 1 m	DW3B 5°, 45 m 1 m	DW4B 4°, 75 m 1 m	UW1B 171°, 72 m 1 m
Boom 2, Burn 2									
Pre-background (30min)	Average	20.2	19.2	24.5	20.6	18.2	17.7	21.5	15.9
Background	Average	24.3	100.1	121.6	53.8	57.6	64.9	40.7	18.4
	µg/m³ above Pre-Background	4.1	80.9	97.1	33.2	39.4	47.2	19.2	2.5
Post-background (15 min)	Average	27.1	24.9	240.3	32.1	46.7	35.8	42.2	22.5
	µg/m³ above Pre-Background	6.9	5.7	215.8	11.5	28.5	18.1	20.7	6.7
Boom 2, Burn 3									
Pre-Burn 30 min	Average	25.6	24.3	29.6	25.2	24.4	23.2	28.3	21.6
Burn	Average	47.6	95.5	43.3	122.4	31.2	107.7	113.0	25.2
	µg/m³ above Pre-Background	22.0	71.2	13.7	97.1	6.8	84.5	84.7	3.6
Post-Burn 15 min	Average	36.2	353.0	190.4	318.9	45.9	235.7	155.1	30.1
	µg/m³ above Pre-Background	10.6	328.7	160.7	293.7	21.5	212.5	126.7	8.5

Boom 1, Burn 3 (Cluster)

		S1C -145°, 35 m UW (upwind) 1 m	S3A 54°, 42 m DW1 1 m	S3A 54°, 42 m DW2 1 m	S3A 54°, 42 m DW3 1 m
Pre-Burn 30 min	Average	25.2	24.3	27.0	26.3
Burn	Average	23.9	39.6	36.5	33.4
	µg/m³ above Pre-Background	-1.4	15.4	9.5	7.1
Post-Burn 15 min	Average	16.9	25.6	26.7	24.8
	µg/m³ above Pre-Background	-8.3	1.3	-0.3	-1.6

Table A-5b **Results of the DataRam Monitoring**

PM-10 Particulates Monitored by the DataRams (Ave µg/m³)

	DW1A 26°,30 m 1 m	DW1B 10°,15 m 1 m	DW1C -18°,30 m 1 m	DW2B 7°,30 m 1 m	DW2C -24°,45 m 1 m	DW3B # 1 5°, 45 m 1 m	DW3B # 2 5°, 45 m 1 m	UW1B 171°, 72 m 1 m
	Boom 3, Burn 1 September 29, 97 (08:46 to 09:35 fro 69 min)							
Pre-burn 15 min	114.9	85.3	89.0	102.8	90.6	92.4	87.6	82.3
Pre-burn 30 min	122.7	90.9	94.2	110.1	97.0	99.4	94.4	90.7
Burn	97.4	75.6	78.8	86.8	82.2	84.8	74.7	72.8
Post-burn 15 min	151.9	84.0	64.3	66.5	65.0	69.3	56.9	52.6
	Boom 3a, Burn 1 September 30, 97 (07:54 to 10:07 for 133 min)							
Pre-burn 15 min	250.6	185.1	204.9	233.4	195.8	197.6	200.9	168.3
Pre-burn 30 min	247.3	184.6	202.9	230.3	195.0	196.7	201.1	166.8
Burn	166.6	126.2	141.5	152.4	134.9	137.8	134.7	131.9
Post-burn 15 min	131.2	109.2	124.5	123.4	120.3	120.8	116.4	114.0

	DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 m 1 m	DW2B 7°, 30 m 1 m	DW3B # 1 5°, 45 m 1 m	DW3B # 2 5°, 45 m 1 m	DW3B # 3 5°, 45 m 1 m	UW1B 171°, 72 m 1 m
	Boom 4, Burn 1 October 01, 97 (08:26 to 09:35 for 69 min)							
Pre-burn 15 min	173.6	135.3	153.9	154.2	148.9	145.3	145.2	134.1
Pre-burn 30 min	162.7	130.3	146.1	147.1	142.4	140.7	138.3	130.6
Burn	149.5	117.5	133.6	133.4	133.5	131.2	122.6	114.1
Post-burn 15 min	125.4	133.8	197.3	106.1	107.5	109.9	97.7	81.9
	Boom 4, Burn 2 October 01, 97 (10:37 to 14:23 for 63 min)							
Pre-burn 15 min	75.0	65.3	74.2	68.4	68.8	68.2	57.9	60.9
Pre-burn 30 min	75.7	68.3	74.2	70.6	70.9	69.7	59.7	62.0
Burn	81.6	516.2	111.6	209.6	188.9	161.3	141.9	57.0
Post-burn 15 min	75.7	383.0	264.0	238.2	156.0	181.4	163.8	51.3

PM-10 Particulates Monitored by the DataRams (Ave µg/m³)

DataRams on U.S. Coast Guard Strike Team Boats

	Boom 2, Burn 1 September 26, 97 (12:47 to 13:52 for 65 min)		**Boom 2, Burn 2** September 26, 97 (14:59 to 16:03 for 64 min)	
	DataRam # 2 DW5B approx. 195 m from edge of pan	DataRam # 1 DW6B approx. 295 m from edge of pan	DataRam # 1 DW5B approx. 195 m from edge of pan	DataRam # 2 DW6B approx. 295 m from edge of pan
Pre-burn 15 min	18.1	12.9		
Pre-burn 30 min	18.1	12.9	28.6	65.1
Burn	80.0	29.8		
Post-burn 15 min	29.7			

	Boom 4, Burn 2 October 01, 97 (10:37 to 11:40 for 63 min)	**Boom 5, Burn 1** October 02, 97 (12:51 to 13:53 for 62 min)	
	USCG-moving 122-1009 m from edge of pan DataRam # 3	USCG-moving 122-1009 m from edge of pan DataRam # 1	USCG-moving 122-1009 m from edge of pan DataRam # 2
Pre-burn 15 min		13.2	10.5
Pre-burn 30 min		14.4	10.3
Burn	83.1	79.7	67.5
Post-burn 15 min			94.0

Table A-6a Carbon Dioxide Recorded by the Metrosonics aq-501 (ppm)

Background

		UW1B 171°, 72 m 0.5 m	UW1B 171°, 72 m 1 m	UW1B 171°, 72 m 2 m	UW1B 171°, 72 m 4 m	S1A 143°, 45 m 1 m	S2A 86°, 45 m 1 m	S3A 54°, 42 m 1 m	S1C -145°, 35 m 1 m	S2C -90°, 45 m 1 m	DW4B 4°,75 m 1 m
Pre-Burn	Average	400	332	405	416	432	339	449			347
Burn	Average	403	327	409	417	445	346	462			345
	ppm above Pre-Burn	3	-5	4	1	13	8	13			-2
Post-Burn	Average	403	325	410	418	456	455	489			406
	ppm above Pre-Burn	3	-7	5	1	25	117	40			59

		DW1A 26°,30 m 0.5 m	DW1A 26°,30 m 1 m	DW1A 26°,30 m 2 m	DW1A 26°,30 m 4 m	DW1B 10°,15 m 0.5 m	DW1B 10°,15 m 1 m	DW1B 10°,15 m 2 m	DW1B 10°,15 m 4 m
Pre-Burn	Average	398	401	392	396	409	401	414	372
Burn	Average	399	401	393	396	407	400	421	370
	ppm above Pre-Burn	1	-1	1	-1	-2	-2	7	-2
Post-Burn	Average	408	397	385	405	405	402	430	295
	ppm above Pre-Burn	10	-5	-7	9	-4	0	16	-77

		DW2B 7°,30 m 0.5 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 4 m	DW3B 5°,45 m 0.5 m	DW3B 5°,45 m 1 m	DW3B 5°,45 m 2 m	DW3B 5°,45 m 4 m
Pre-Burn	Average	437	469	377	400	416	432	403	375
Burn	Average	434	453	379	403	422	436	406	380
	ppm above Pre-Burn	-3	-15	2	3	6	5	3	5
Post-Burn	Average	443	460	381	405	432	460	411	386
	ppm above Pre-Burn	6	-8	4	5	16	28	9	11

Boom 2, Burn 1

		UW1B 171°, 72 m 0.5 m	UW1B 171°, 72 m 1 m	UW1B 171°, 72 m 2 m	UW1B 171°, 72 m 4 m	S1A 143°, 45 m 1 m	S2A 86°, 45 m 1 m	S3A 54°, 42 m 1 m	S1C -145°, 35 m 1 m	S2C -90°, 45 m 1 m	DW4B 4°,75 m 1 m
Pre-Burn	Average	609	454	411	436	407	306	412		452	413
Burn	Average	638	473	428	456	414	196	414		479	410
	ppm above Pre-Burn	29	19	18	20	8	-110	3		27	-3
Post-Burn	Average	647	484	424	461	421	241	433		517	382
	pps above Pre-Burn	38	30	13	25	15	-65	21		65	-31

		DW1A 26°,30 m 0.5 m	DW1A 26°,30 m 1 m	DW1A 26°,30 m 2 m	DW1A 26°,30 m 4 m	DW1B 10°,15 m 0.5 m	DW1B 10°,15 m 1 m	DW1B 10°,15 m 2 m	DW1B 10°,15 m 4 m
Pre-Burn	Average	393		413	383	338	411	421	385
Burn	Average	390		439	399	373	432	438	418
	ppm above Pre-Burn	-4		26	16	35	21	17	34
Post-Burn	Average	367		435	391	369	414	422	409
	ppm above Pre-Burn	-27		22	8	31	2	1	24

		DW2B 7°,30 m 0.5 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 4 m	DW3B 5°,45 m 0.5 m	DW3B 5°,45 m 1 m	DW3B 5°,45 m 2 m	DW3B 5°,45 m 4 m
Pre-Burn	Average	426	414	402	361	381		399	407
Burn	Average	430	419	429	378	385		422	426
	ppm above Pre-Burn	3	5	28	17	4		23	18
Post-Burn	Average	405	393	410	364	367		408	414
	ppm above Pre-Burn	-22	-21	9	3	-14		9	6

Boom 2, Burn 2

		UW1B 171°, 72 m 0.5 m	UW1B 171°, 72 m 1 m	UW1B 171°, 72 m 2 m	UW1B 171°, 72 m 4 m	S1A 143°, 45 m 1 m	S2A 86°, 45 m 1 m	S3A 54°, 42 m 1 m	S1C -145°, 35 m 1 m	S2C -90°, 45 m 1 m	DW4B 4°,75 m 1 m
Pre-Burn	Average	642	490	407	459	428		439	560	532	317
Burn	Average	662	501	409	465	435		438	574	558	309
	ppm above Pre-Burn	21	11	2	6	7		0	14	26	-8
Post-Burn	Average	690	491	416	453	427		397	583	522	329
	ppm above Pre-Burn	48	1	8	-5	-1		-42	23	-10	11

		DW1A 26°,30 m 0.5 m	DW1A 26°,30 m 1 m	DW1A 26°,30 m 2 m	DW1A 26°,30 m 4 m	DW1B 10°,15 m 0.5 m	DW1B 10°,15 m 1 m	DW1B 10°,15 m 2 m	DW1B 10°,15 m 4 m
Pre-Burn	Average	372		425	397	365	409	425	375
Burn	Average	389		437	407		430	446	415
	ppm above Pre-Burn	16		12	10		21	22	40
Post-Burn	Average	367		437	392		431	442	440
	ppm above Pre-Burn	-5		12	-5		21	17	66

		DW2B 7°,30 m 0.5 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 4 m	DW3B 5°,45 m 0.5 m	DW3B 5°,45 m 1 m	DW3B 5°,45 m 2 m	DW3B 5°,45 m 4 m
Pre-Burn	Average	442	395	414	363	392		400	410
Burn	Average	417	395	439	378	423		437	430
	ppm above Pre-Burn	-25	0	25	16	31		37	20
Post-Burn	Average	376	369	429	378	424		434	432
	ppm above Pre-Burn	-66	-27	15	16	33		33	23

Table A-6b

Carbon Dioxide Recorded by the Metrosonics aq-501 (ppm)

Boom 2. Burn 3

		UW1B 171°, 72 m 0.5 m	UW1B 171°, 72 m 1 m	UW1B 171°, 72 m 2 m	UW1B 171°, 72 m 4 m	S1A 143°, 45 m 1 m	S2A 86°, 45 m 1 m	S3A 54°, 42 m 1 m	S1C -145°, 35 m 1 m	S2C -90°, 45 m 1 m	DW4B 4°,75 m 1 m
Pre-Burn	Average	673	491	410	444	430		407	572	548	293
Burn	Average	705	493	427	453	428		401	559	522	324
	ppm above Pre-Burn	32	1	17	9	-2		-6	-12	-26	31
Post-Burn	Average	709	483	427	452	403		360	460	415	380
	ppm above Pre-Burn	36	-8	17	8	-27		-48	-112	-132	87

		DW1A 26°,30 m 0.5 m	DW1A 26°,30 m 1 m	DW1A 26°,30 m 2 m	DW1A 26°,30 m 4 m	DW1B 10°,15 m 0.5 m	DW1B 10°,15 m 1 m	DW1B 10°,15 m 2 m	DW1B 10°,15 m 4 m
Pre-Burn	Average	373		422	393	369	415	444	398
Burn	Average	374		472	401	397	436	460	433
	ppm above Pre-Burn	0		49	8	28	21	16	35
Post-Burn	Average	387		492	399	422	451	470	477
	ppm above Pre-Burn	14		70	6	53	36	26	79

		DW2B 7°,30 m 0.5 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 4 m	DW3B 5°,45 m 0.5 m	DW3B 5°,45 m 1 m	DW3B 5°,45 m 2 m	DW3B 5°,45 m 4 m
Pre-Burn	Average	392	386	416	373	415		416	426
Burn	Average	390	386	447	387	441		452	441
	ppm above Pre-Burn	-2	0	31	14	26		36	15
Post-Burn	Average	369	373	466	396	436		467	446
	ppm above Pre-Burn	-23	-13	49	23	21		51	20

Boom 3, Burn 1

		UW1B 171°, 72 m 0.5 m	UW1B 171°, 72 m 1 m	UW1B 171°, 72 m 2 m	UW1B 171°, 72 m 4 m	S1A 143°, 45 m 1 m	S2A 86°, 45 m 1 m	S3A 54°, 42 m 1 m	S1C -145°, 35 m 1 m	S2C -90°, 45 m 1 m	DW4B 4°,75 m 1 m
Pre-Burn	Average	443	481	461	437	461	389	480	368		361
Burn	Average	436	486	461	442	478	461	512	423		328
	ppm above Pre-Burn	-6	5	0	5	17	71	32	56		-33
Post-Burn	Average	429	524	448	470	585	358	627			
	ppm above Pre-Burn	-14	43	-13	32	124	-31	147			

		DW1A 26°,30 m 0.5 m	DW1A 26°,30 m 1 m	DW1A 26°,30 m 2 m	DW1A 26°,30 m 4 m	DW1B 10°,15 m 0.5 m	DW1B 10°,15 m 1 m	DW1B 10°,15 m 2 m	DW1B 10°,15 m 4 m
Pre-Burn	Average	427		433	576	429	456	439	
Burn	Average	448		437	572	431	460	447	
	ppm above Pre-Burn	21		4	-4	2	4	8	
Post-Burn	Average	498		412	627	408	457	497	
	ppm above Pre-Burn	71		-21	51	-20	1	58	

		DW2B 7°,30 m 0.5 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 4 m	DW3B 5°,45 m 0.5 m	DW3B 5°,45 m 1 m	DW3B 5°,45 m 2 m	DW3B 5°,45 m 4 m
Pre-Burn	Average		504	338	444	421		465	445
Burn	Average		522	277	436	425		462	451
	ppm above Pre-Burn		18	-61	-8	5		-2	6
Post-Burn	Average		640	261	425	411		458	472
	ppm above Pre-Burn		136	-78	-19	-10		-6	27

Boom 3a, Burn 1

		UW1B 171°, 72 m 0.5 m	UW1B 171°, 72 m 1 m	UW1B 171°, 72 m 2 m	UW1B 171°, 72 m 4 m	S1A 143°, 45 m 1 m	S2A 86°, 45 m 1 m	S3A 54°, 42 m 1 m	S1C -145°, 35 m 1 m	S2C -90°, 45 m 1 m	DW4B 4°,75 m 1 m
Pre-Burn	Average	476		459	448	487		443	475		590
Burn	Average	458	523	456	441	533		510	428		438
	ppm above Pre-Burn	-18	523	-3	-7	46		67	-47		-153
Post-Burn	Average	442	564	458	464	663		585			418
	ppm above Pre-Burn	-34	564	-1	16	176		142			-172

		DW1A 26°,30 m 0.5 m	DW1A 26°,30 m 1 m	DW1A 26°,30 m 2 m	DW1A 26°,30 m 4 m	DW1B 10°,15 m 0.5 m	DW1B 10°,15 m 1 m	DW1B 10°,15 m 2 m	DW1B 10°,15 m 4 m
Pre-Burn	Average			494	586	512	447	459	662
Burn	Average			452	614	440	421	474	523
	ppm above Pre-Burn			-43	28	-73	-25	15	-139
Post-Burn	Average			448	654	423	413	511	473
	ppm above Pre-Burn			-46	68	-89	-34	52	-189

		DW2B 7°,30 m 0.5 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 4 m	DW3B 5°,45 m 0.5 m	DW3B 5°,45 m 1 m	DW3B 5°,45 m 2 m	DW3B 5°,45 m 4 m
Pre-Burn	Average		529	472	478	449		522	540
Burn	Average		564	293	447	438		477	479
	ppm above Pre-Burn		36	-178	-31	-11		-45	-61
Post-Burn	Average		636	266	432	445		463	481
	ppm above Pre-Burn		107	-206	-46	-4		-60	-59

Table A-7a **Carbon Dioxide Recorded by the Armstrong CD-1 (ppm)**

Background

		DW1C -18°,30 m 4 m	DW1C 7°,30 m 2 m	DW1C -18°,30 m 1 m	DW1C -18°,30 m 0.5 m	DW2B 7°,30 m 4 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 0.5 m
Pre-Burn	Average	350	342	333	342	359	383	353
Burn	Average	352	340	330	347	357	388	355
	ppm above Pre-Burn	3	-2	-3	5	-2	5	2
Post-Burn	Average	370	341	332	349	357	397	352
	ppm above Pre-Burn	20	-1	-1	7	-2	14	-1

Boom 2, Burn 1

		DW1C -18°,30 m 4 m	DW1C -18°,30 m 1 m	DW1C -18°,30 m 0.5 m	DW2B 7°,30 m 4 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 0.5 m
Pre-Burn	Average	417	400	411	348	355	478	334
Burn	Average	394	398	413	353	355	489	339
	ppm above Pre-Burn	-23	-1	2	6	0	11	5
Post-Burn	Average	380	395	411	328	353	490	336
	ppm above Pre-Burn	-36	-5	0	-20	-2	12	1

Boom 2, Burn 2

		DW1C -18°,30 4 m	DW1C -18°,30 1 m	DW1C -18°,30 0.5 m	DW2B 7°,30 m 4 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 0.5 m
Pre-Burn	Average	412	398	412	336	365	494	332
Burn	Average	400	402	418	356	352	507	340
	ppm above Pre-Burn	-12	4	6	20	-13	12	8
Post-Burn	Average	380	404	418		348	505	332
	ppm above Pre-Burn	-32	6	6		-17	11	1

Boom 2, Burn 3

		DW1C -18°,30' m 4 m	DW1C -18°,30' m 1 m	DW1C -18°,30' m 0.5 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 0.5 m
Pre-Burn	Average	407	407	421	361	516	326
Burn	Average	459	412	426	349	523	334
	ppm above Pre-Burn	52	5	5	-12	8	8
Post-Burn	Average	383	406	420	339	523	346
	ppm above Pre-Burn	-24	-1	-2	-22	8	20

Boom 3, Burn 1

		DW1C -18°,30 m 4 m	DW1C -18°,30 m 1 m	DW1C -18°,30 m 0.5 m	DW2B 7°,30 m 4 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 0.5 m
Pre-Burn	Average	376	381	393	398	375	403	379
Burn	Average	515	402	411	404	369	428	381
	ppm above Pre-Burn	140	21	19	7	-5	24	2
Post-Burn	Average	418	420	428	396	389	463	374
	ppm above Pre-Burn	42	39	35	-2	14	59	-6

Table A-7b Carbon Dioxide Recorded by the Armstrong CD-1 (ppm)

Boom 3a, Burn 1

		DW1C -18°,30 m 4 m	DW1C -18°,30 m 2 m	DW1C -18°,30 m 1 m	DW1C -18°,30 m 0.5 m
Pre-Burn	Average	215	274	283	298
Burn	Average	389	340	339	348
	ppm above Pre-Burn	174	67	56	50
Post-Burn	Average	344	392	384	388
	ppm above Pre-Burn	129	118	101	90

Boom 4, Burn 1

		DW1C -18°,30 m 4 m	DW1C -18°,30 m 1 m	DW1C -18°,30 m 0.5 m	DW2B 7°,30 m 4 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 0.5 m
Pre-Burn	Average	457	448	453	437	361	418
Burn	Average	553	467	462	445	366	420
	ppm above Pre-Burn	95	19	9	8	5	2
Post-Burn	Average	487	471	464	433	371	408
	ppm above Pre-Burn	29	23	11	-4	9	-10

Boom 4, Burn 2

		DW1C -18°,30 m 4 m	DW1C -18°,30 m 2 m	DW1C -18°,30 m 1 m	DW1C -18°,30 m 0.5 m	DW2B 7°,30 m 4 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 0.5 m
Pre-Burn	Average	506	422	464	458	439	361	370	399
Burn	Average	591	420	456	453	433	368	373	393
	ppm above Pre-Burn	85	-2	-9	-6	-6	7	2	-6
Post-Burn	Average	509	421	457	453	432	375	376	390
	ppm above Pre-Burn	3	-1	-8	-6	-7	14	6	-9

Boom 4, Burn 3

		DW1C -18°,30 m 4 m	DW1C -18°,30 m 1 m	DW1C -18°,30 m 0.5 m	DW2B 7°,30 m 4 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 0.5 m
Pre-Burn	Average	548	461	457	440	375	374	385
Burn	Average	625	463	460	438	374	374	384
	ppm above Pre-Burn	77	2	4	-3	-1	0	-1
Post-Burn	Average	522	470	469	438	383	383	391
	ppm above Pre-Burn	-26	10	12		8	9	6

Boom 5, Burn 1

		DW1C -18°,30 m 4 m	DW1C -18°,30 m 1 m	DW1C -18°,30 m 0.5 m	DW2B 7°,30 m 4 m	DW2B 7°,30 m 2 m	DW2B 7°,30 m 1 m	DW2B 7°,30 m 0.5 m
Pre-Burn	Average	420	395	415	397	404	424	383
Burn	Average	465	396	423	397	400	422	380
	ppm above Pre-Burn	44	1	8	0	-4	-2	
Post-Burn	Average	383	392	421	366	406	426	380
	ppm above Pre-Burn	-38	-3	6	-30	2	1	

Table A-8 **Burns and Environmental Conditions**

Burn Description	Date	Burn Time (min.)	Temperature* (°C)	Humidity* (rel %)	Wind Speed and Direction** % time, velocity (knots), direction
Boom 1 Burn 1	22-Sep	65	22.1	52	
Boom 1 Burn 2	25-Sep	60	no data taken - raining		
Boom 1 Burn 3	25-Sep	62	22.7	89.3	
Boom 2 Burn 1	26-Sep	65	26.2	67.1	60% : 4 to10 : 10° 30% : 1 to 8 : 30°
Boom 2 Burn 2	26-Sep	64	27.1	59.5	50% : 4 to10 : 30° 30% : 4 to 10 : 10°
Boom 2 Burn 3	26-Sep	63	27.3	62.8	45% : 2 to 8 : 10° 35% : 2 to 8 : 30°
Boom 3 Burn 1	29-Sep	39	25.1	87	45% : 1 to 6 : - 40° 35% : 1 to 6 : -15°
Boom 3a Burn 1	30-Sep	133	22.6	85.9	20% : 1 to 2 : - 130° 15% : 1 to 2 : 75° 15% : 1 to 2 : -105°
Boom 4 Burn 1	1-Oct	69	25.3	86.5	25% : 1 to 8 : - 35° 22% : 1 to 8 : 10° 20% : 1 to 8 : -60°
Boom 4 Burn 2	1-Oct	63	28.4	71.4	50% : 4 to 10 : - 30° 35% : 4 to 10 : 30°
Boom 4 Burn 3	1-Oct	64	30.4	56.5	80% : 7 to 10 : 30°
Boom 5 Burn 1	2-Oct	62	25.4	30.4	

**values are averages from an automatic weather station*
*** wind speed is in knots and direction is the degrees off the instrument centre line*