Instrumentation and Techniques for Monitoring the Air Emissions During In-situ Oil/Fuel Burning Operations

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Abstract

An evaluation of two models of portable real-time aerosol monitors was conducted. The equipment included the MIE Inc. (Bedford, MA) Model RAM-1 and DataRAM units. The test program was carried out in conjunction with the United States Coast Guard (USCG) sponsored 1997 mesoscale fire boom trials in Mobile, Alabama. Two experiments were carried out. The first was to examine the reproducibility of the data from several units located at the same sampling station. Results indicated that under the experimental conditions the best reproducibility, based on standard deviation from the mean value, for the DataRAM was 11%, for the RAM-1 was 64% and for the entire array was 42%. The second experiment was to compare the results from monitors on moving sample platforms to those of stationary sample platforms. With a limited data set, results from the moving sampling platform (77 $\mu g/m^3$) were slightly higher than those of the stationary platform (51 $\mu g/m^3$).

1.0 Objective

The objective of this paper is to present data from the evaluation of the RAM-1 and DataRAM real-time aerosol monitors under specific field conditions. Specifically, information is presented on the following goals:

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- comparison of the reproducibility of RAM-1 and DataRAM values when several of the units are placed in close proximity (cluster experiment); and,
- comparison of the information generated by a DataRAM on a mobile sampling platform versus the information from a stationary sampling platform.

2.0 Introduction

In-situ burning has evolved significantly over the past two decades as a viable oil spill countermeasure, and is now given serious consideration as a cleanup option during spills of petroleum hydrocarbons on water. Ongoing research efforts continue to further the knowledge of the impact in-situ burning has on the environment and of health and safety related issues. Recently, the focus of efforts has shifted toward applying the research to operational concerns. A need was identified in McGratton *et al.* (1995) for the review and development of operational air monitoring techniques for use during an actual spill.

Environment Canada's Emergencies Science Division (ESD) and the US Environmental Protection Agency- Environmental Response Group (EPA-ERT) have active programs to evaluate scientific instrumentation and develop analytical methods suitable for field operations. Examples of this work can be found in Campagna *et al.*, 1994 and Environment Canada, 1997.

Mesoscale burn experiments carried out over the past few years (Evans *et al.* 1992, Walton *et al.* 1993, Fingas *et al.* 1993, Fingas *et al.* 1994, Fingas *et al.* 1996) obtained much needed data about the fate of the oil and in-situ burning emissions into the environment. An ancillary benefit of participation in these projects was the significant increase in the knowledge of the unique challenges associated with monitoring air emissions from crude oil and petroleum fuel fires.

During the 1997 burn program ESD, EPA-ERT and the United States Coast Guard Gulf Strike Team (USCG-GST) were tasked with carrying out air monitoring using an array of stationary air sampling equipment as well as real-time monitoring equipment. This paper discusses the results of two studies undertaken during the 1997 burn trials focussed towards evaluating the operational limitations of real-time aerosol monitors for in-situ diesel fuel fires.

3.0 Procedures

The following paragraphs describe the instrumentation and experimental conditions under which the program was carried out.

These monitors are commercially available pieces of equipment commonly used in the occupational health and safety industry. The RAM-1 (MIE Inc, Bedford MA) portable real-time aerosol monitor allows for the continuous measurement of aerosols.

Operationally, air is continuously drawn through the RAM-1 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 centred 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 the detectors (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 size fractions. The omni-directional sampling head improves sampling consistency and is capable of measuring the total particulate size fraction. The RAM-1 was not designed with the capability for operation as a specific PM10 or PM2.5 sampling unit. The cyclone pre-collector limits the sampling to particulates up to 10 μm however, the actual sampling fraction is 2.5-10 μm and the respective proportion of that fraction is based on the penetration of the particulate through the cyclone collector. One hundred percent of the particles with size less than 2.5 μm penetrate the cyclone collector. The penetration of the particulate through the cyclone collector decreases exponentially to 0 percent as the particulate size increases to 10 μm. 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 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 Inc. CR10 Data Logger, Logan UT). The multiple values from the RAM-1 were averaged over a period of one minute. The analog output was in the 0-10 volt range. Controls and settings which affect the digital display have a corresponding effect on to the analog output. Data recorded by the data logger was mathematically converted to concentration in μg/m^3 after the trials.

The instrument was operated using an external solar power source. The RAM-1 units were placed about the sampling field in the noted locations (Figure 20) and barring instrument failure, remained on station for the duration of the project. Maintenance and calibration of the units was undertaken on a regular basis in co-ordination with the days in which the burn program was carried out.

The DataRAM (MIE Inc, Bedford MA) is an updated version of the RAM-1. The monitor is a portable instrument employing a similar combination of optical and electronic technology to measure the concentration of airborne particulate. The advantage of this unit over the RAM-1 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 0-10 μm particulate fraction or the 0-2.5 μm particulate fraction. 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-1 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.

Equipment was deployed about the burn pan, for this and other experiments, as indicated in Figure 20. Relevant to the cluster experiment, three RAM-1 and two or three DataRAM monitors were placed in a cluster close to each other located at the DW3B sampling station. The exception is for the third burn for the first boom

(designated Boom 1, Burn 3), during which the cluster was repositioned at the S3A sampling station due to wind conditions. Each boom was to undergo three burn trials. Thus each trial was named after the sequential boom number (1 to 5) and burn number (1 to 3). Throughout the burn program the units were set up to measure either the total aerosol particulate levels, particulate matter of 10 μm or less (PM10) or particulate matter of 2.5 μm or less (PM2.5). Both the RAM-1 and DataRAM were set up to measure the total aerosol fraction during the background testing through to boom 2 burn 3. During boom 3 burn 1, boom 3a burn 1 and boom 4 burn 1 and 2 the DataRAM was set up to measure PM10 particulate fraction. The configuration of the DataRAM was set to PM2.5 for boom 4 burn 3 and boom 5 burn 1. Throughout these same trials the cyclone sampling head was placed on the clustered RAM-1 units permitting them to measure over the size range of 2.5 μm to 10 μm.

For the second goal, DataRAM monitors set to measure PM10 aerosol levels were operated on boats positioned several tens to hundreds of meters off the coast of the island. For one segment of the program, the boats remained at a fixed location while during another series of burns the boats moved along a path perpendicular to the direction of the plume. Members of the USCG-GST carried out the exercise. Following the completion of the burn the information collected by the monitors was uploaded to a computer. The files were processed following the completion of the project.

The RAM-1 and DataRAM units were placed at the same location at sampling station DW3B. Maintenance and calibration of the units was undertaken on a regular basis in co-ordination with the days in which the burn program was carried out. Instruments were operated for a minimum of 15 minutes prior to and following each burn.

4.0 Results

Table 1 lists a summary of the RAM-1 and DataRAM results for the burn trials in which a minimum of two units of each type were stationed at the same sampling location described as the cluster experiment. The table provides the name of each burn trial as boom #, burn # and the size or fraction of the particulate matter measured. The average concentration in $\mu g/m^3$ for each unit at the station has been detailed. The average value was calculated from data logged over the duration of the burn. There has been a minimal amount of data processing and the results represent the average of the values which would have been observed directly from the digital readout of the monitor during the burn trial.

The standard deviation of the data set was calculated using the traditional statistical formula. It is noted that the magnitude of the deviation is often greater than the magnitude of the average for the data set, indicating a distribution down into negative values. Of course ambient particulate levels set the lower limit, and the high deviation values are a result of the irregular positive peaks of large magnitude. These values are therefore not representative of a distribution about a mean, but rather simply an indicator of the high variability of the data obtained.

Table 1 RAM-1 and DataRAM Results for the Cluster Experiment

Description	RAM-1* $\mu g/m^3$	DataRAM* $\mu g/m^3$
Boom 1 burn 3 Measuring total aerosol fraction	68 ± 118 27 ± 126 23 ± 113	40 ± 76 36 ± 40 33 ± 29
Boom 3 burn 1 Measuring PM10 aerosol fraction	210 ± 21 10 ± 0 16 ± 4	85 ± 7 75 ± 6
Boom 3a burn 1 Measuring PM10 aerosol fraction	172 ± 228 530 ± 798 134 ± 61	138 ± 5 135 ± 4
Boom 4 burn 1 Measuring PM10 aerosol fraction	0 ± 0 196 ± 9 188 ± 9	134 ± 11 131 ± 12 123 ± 10
Boom 4 burn 2 Measuring PM10 aerosol fraction	0 ± 0 249 ± 173 253 ± 245	189 ± 261 161 ± 157 142 ± 131
Boom 4 burn 3 RAM-1 measuring up to PM10 and DataRAM measuring PM2.5 aerosol fraction	1 ± 6 312 ± 368 329 ± 442	156 ± 246 157 ± 231 168 ± 262
Boom 5 burn 1 RAM-1 measuring up to PM10 and DataRAM measuring PM2.5 aerosol fraction	12 ± 72 196 ± 361 193 ± 402	100 ± 251 98 ± 235 82 ± 167

* Average reading recorded (± standard deviation) over the duration of the burn period. Not corrected for pre-burn values.

Table 2 lists the data collected by all of the RAM-1 units on site. Data presented has been categorized for each individual burn. An example of this is given by the subtitle Background and Boom 1, Burn 3 trials. A Background trial was carried out on a day in which no burns occurred in order to obtain information on the performance of the equipment.

Experimental parameters such as station number, location, sampling height and aerosol fraction are included along the top of the table above each column. The station number is described as DWXX or UWXX. The location of the station is listed as degrees off of the centre instrument line and distance (metres) from the centre of the tank. Sampling height, in metres, and the particulate size fraction the monitor was set to measure are included.

Within the contents of the table are the average values recorded for a specific time period prior to the start of the burn, for the time period during the burn and for a specific time period following the burn. Finally, also listed in the table are values described as concentration ($\mu g/m^3$) above Pre-burn. These are numbers calculated following the trials to note the change in the measurements by the unit during and

after the burn. The RAM-1 units were set up to measure the total aerosol fraction for the duration of the project with the exception of the units at station DW3B.

Data is listed in Table 3 for each of the DataRAM units with similar format and content to that of Table 2. A single unit was positioned at the station DW3B for the burn series titled background through to boom 2, burn 3. The equipment was set to measure the total aerosol fraction.

Results from the DataRAM configured to measure the PM10 fraction are given in Table 4. A second DataRAM was positioned at station DW3B beginning at boom 3 burn 1. The cluster of three DataRAM and RAM-1 units was completed for boom 4 burn 1. DataRAM apparatus used by the USCG-GST were consistently set up for PM10 analysis. The two pieces of equipment were deployed on boats at fixed positions (approximately 195 m and 295 m downwind) for boom 2, burn 1 and 2. A single unit was on a moving boat (ranging from approximately 122 m to 1009 m downwind) during boom 4 burn 2 while two units were positioned on moving platforms for boom 5 burn 1.

Table 5 contains the results recorded by the DataRAM equipment with PM2.5 sampling intakes. For both Table 4 and 5, the calculated values for concentration ($\mu g/m^3$) above Pre-burn were not included. The Pre-burn value was often higher than the burn average and would have resulted in a negative calculated value. Additional data processing including slope correction would have been required and would likely had an impact the comparison of results.

Figures 1 through 10 graphically display the recorded concentration versus time for the RAM-1 monitors. The zero point along the x axis marks the start of the burn trial. Dashed vertical lines indicate the start of the Pre-burn period and completion of the burn trial. The scale of the graph was selected so as to include the full range of the recorded information. Information in one legend provides the name of the specific burn trial and measuring parameters. The other legend lists the sampling stations displayed in the figure. For comparison purposes, instruments at stations other than just the "cluster" of DW3B have been provided. Stations DW1B and DW2B were positioned along the same axis as DW3B at 15 m and 30 m from the centre of the test tank respectively.

Concentration versus time plots for the DataRAM equipment have been given in Figures 11 through 19. The figures represent the series of burns including and following boom 3 burn 1, when the cluster experiment and/or USCG boats were involved.

5.0 Discussion

A review of the information presented in Table 1 provides insight into the reproducibility of a cluster of RAM-1 and DataRAM equipment. All six units were stationed within 2 m of each other. The results are the average values over the duration of the burn and have not been corrected for Pre-burn readings. When considering the average results for each unit over all seven trials there are some anomalies in the reproducibility of the results. The DataRAM appears to generate more reproducible results between several distinct units than the RAM-1. For almost all burns the results from the three DataRAM pieces were of the same order of

magnitude however the absolute value of the difference between individual averages for any one burn ranged from 3 $\mu g/m^3$ to 47 $\mu g/m^3$. This absolute difference is within expected limits for a portable real-time monitor but may become significant if the values displayed by the monitor were to be compared to a specific numeric limit.

The RAM-1 results showed greater variation between each unit. In cases such as boom 3 burn 1, boom 4 burn 1,2 and 3 and boom 5 burn 1 at least one of the results was an order of magnitude different from the others. For the RAM-1 the absolute value of the difference between individual average results for any one burn ranged from 3 $\mu g/m^3$ to 350 $\mu g/m^3$. The DataRAM possesses advanced internal software and data logging capability as compared to the RAM-1 and this may be the reason for the improved reproducibility. A variation in results of 350 $\mu g/m^3$ is beyond acceptable limits for a portable unit.

Reproducibility of the results from both types of equipment appeared highest for boom 1 burn 3 where the six results ranged from 23 $\mu g/m^3$ to 68 $\mu g/m^3$. The mean of the six values was 38 $\mu g/m^3$ with a standard deviation of 16 $\mu g/m^3$ or 42%. The mean of the three RAM-1 values was 39 ± 25 (64%) $\mu g/m^3$ while the mean of the DataRAM values was 36 ± 4 (11%) $\mu g/m^3$. Generally speaking, interpretation of the reproducibility of the results between the two different models is dependent upon the purpose of the equipment. In the role of an air monitor and in consideration of the limitations of a portable monitor, the two different models generate comparable results. When used to generate scientifically defendable data the reproducibility between the two models is not within the acceptance levels of standardized protocols.

The standard deviation was calculated for the entire data set recorded for each monitor. The sample distribution is not ideal for statistical treatment with standard deviation. In practical terms the concentration values would not be found below the ambient value. The intention of including the standard deviation was to show the high variation in the data recorded during the burn. Variation in the data is displayed in Figures 8, 9,10, 14, 15 and 18 which show concentration versus time for the individual units. On the days displayed in these figures, the wind direction and intensity were optimal and the particulate in the air was observed to fall approximately in line with the cluster sampling station. The non-homogenous nature of the wind conditions and smoke particulate are the primarily influences on the variation in readings. Reporting only the average value recorded over the burn time tends to de-emphasize the range of the results actually recorded and does not adequately describe the conditions which an on-site operator would be observing.

Tables 2 through 5 permit the comparison of the results from the cluster of monitors at station DW3B to the results of the units stationed about the remainder of the field. Several trends are observed. The average results from the monitors clustered at DW3B have a lower relative spread than the average results of all units about the entire field. This is expected as individual results are highly influenced by the location of the monitors relative to the particulate in the air. The reproducibility of results for total, PM10 and PM2.5 aerosol fraction values appears to be independent of the aerosol fraction sampled. In Table 2, boom 4, burn 2 the average reading of the upwind RAM-1 monitor was 361 $\mu g/m^3$ and the cluster units downwind had results of less than 253 $\mu g/m^3$. Thus, during a burn itself, it may not

be possible to correct the observed reading of a downwind monitor with the observed reading of and upwind monitor.

There are limitations on the real-time information displayed by the equipment. The figures showing concentration data versus time usually include the clustered monitors with others from about the field for comparison purposes. An interesting observation regarding real-time monitors is illustrated in Figure 2 and 12. In Figure 2 note the erratic behaviour of the plot for the DW1B monitor in comparison to the other plots. All equipment underwent regular calibration and evaluation, however real-time monitors in general occasionally show unique signal patterns. It is often a function of the sampling environment and/or internal software problems. In Figure 12 the results from all monitors shows a slight decline in concentration readings over the burn period. Changes to the surrounding environmental conditions such as a reduction in humidity as well as changes within the internal operating system of the equipment are often the cause of this phenomena. Reporting the average result over a specified time period is an accepted procedure. However working with average results tends to mask the variability of the data recorded over time for an individual monitor and with respect to other monitors. For example, consider Figure 9 and 14. These two figures display the results for the six clustered monitors during the boom 4, burn 3 trial. At the 36 minute mark after the initiation of the burn the readings from the three RAM-1 units were 1270, 955 and 143 $\mu g/m^3$ and the three DataRAM units showed 726, 676 and 541 $\mu g/m^3$. These results show the variation in displayed results at a moment in time and this is what an operator would be exposed to. Following the trials the data can be corrected. However, an on-site operator viewing the data in isolation would not have the benefit of being able to compare the plots of each of the units and determine that the readings are not absolute.

Information contained in Table 4 and Figures 16, through 19 presents results relative to the discussion of the second goal, a comparison of results generated by a DataRAM sampling on a stationary platform versus a moving platform. Like the land based DataRAM units the average values tabled tend to mask the variation in the actual data observed and recorded while the burn was in progress. Overall the average particulate values do not provide conclusive information on the impact of the sampling platform on results. The stationary platform (51 $\mu g/m^3$ average for all instruments) and moving platform (77 $\mu g/m^3$ average for all instruments) are similar results although not numerically equivalent. This would indicate that there is inconclusive evidence that the operation of the boat influenced the average results of the DataRAM. Upon closer review of the numbers various deviations are observed. For example in the case of the boom 2, burn 1 trial the stationary platform at 295 m had an average concentration less than that for the platform at 195 m as expected. This was not the case for boom 2, burn 2. For these two burn trials the platforms were not on station to collect pre and post burn readings. This increases the difficulty in evaluating the performance of the monitors. Operational requirements would be best served by ensuring an adequate sampling period has been achieved.

6.0 Conclusion

A series of experiments was performed to evaluate the reproducibility of several RAM-1 and DataRAM real-time aerosol monitors exposed to the conditions produced by a mesoscale in-situ diesel fuel burn. Three of each type were stationed within a circle with a diameter of 2 m. All aerosol sampling size fractions were tested. Results showed that the reproducibility of the average readings recorded during the trials, without any data processing, were not at levels expected for scientific research. Under the experimental conditions employed the results of the instruments clustered together remain influenced by the location of the monitors relative to the particulate in the air. This may be a concern when comparing individual results to air quality standards.

With the described experimental conditions, tests to review the impact of a moving sampling platform versus a stationary platform showed the moving platform had an average result for several burns which was similar to those of the stationary platform.

Limitations on the real-time information displayed by the equipment and the treatment of recorded data were discussed. Operational plans to deploy these real-time aerosol monitors should included confidence limits on the data displayed and the real-time information should be confirmed with post-sampling treatment of the logged data.

7.0 References

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Table 2 Average Aerosol Results Monitored by the RAM-1 During Burn Period (µg/m³)

		Background					
		DW1A 26°, 30 m 1 m Total	DW1B 10°, 15 m 1 m Total	DW1C -18°, 30 m 1 m Total	DW2A 27°, 45 m 1 m Total	DW2B 7°, 30 m 1 m Total	DW2C -24°, 45 m 1 m Total
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 Total	DW3B 5°, 45 m 1 m Total	DW3B 5°, 45 m 1 m Total	DW3B 5°, 45 m 1 m Total	DW3C -29°, 75 m 1 m Total	DW4B 4°, 75 m 1 m Total	UW1B 171°, 72 m 1 m Total
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 Total	S3A 54°, 42 m 1 m Total	S3A 54°, 42 m 1 m Total
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

Background: September 24, 97 from 10:17 to 11:17 for a total Background period of 60 minutes

Boom 1, Burn 3: 14:34 to 15:36 for a total burn period of 62 minutes

Table 2 Average Aerosol Results Monitored by the RAM-1 During Burn Period (µg/m³)

Boom 2, Burn 1

		DW1A 26°, 30 m 1 m Total	DW1B 10°, 15 m 1 m Total	DW1C -18°, 30 m 1 m Total	DW2A 27°, 45 m 1 m Total	DW2B 7°, 30 m 1 m Total	DW2C -24°, 45 m 1 m Total
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 Total	DW3B 5°, 45 m 1 m Total	DW3B 5°, 45 m 1 m Total	DW3B 5°, 45 m 1 m Total	DW3C -29°, 75 m 1 m Total	DW4B 4°, 75 m 1 m Total	UW1B 171°, 72 m 1 m Total
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 Total	DW1B 10°, 15 m 1 m Total	DW1C -18°, 30 m 1 m Total	DW2A 27°, 45 m 1 m Total	DW2B 7°, 30 m 1 m Total	DW2C -24°, 45 m 1 m Total
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 Total	DW3B 5°, 45 m 1 m Total	DW3B 5°, 45 m 1 m Total	DW3B 5°, 45 m 1 m Total	DW3C -29°, 75 m 1 m Total	DW4B 4°, 75 m 1 m Total	UW1B 171°, 72 m 1 m Total
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

Boom 2, Burn 1: 12:47 to 13:52 for a total burn period of 65 minutes

Boom 2, Burn 2: 14:59 to 16:03 for a total burn period of 64 minutes

Table 2 Average Aerosol Results Monitored by the RAM-1 During Burn Period (µg/m³)

Boom 2, Burn 3

		DW1A 26°, 30 m 1 m Total	DW1B 10°, 15 m 1 m Total	DW1C -18°, 30 m 1 m Total	DW2A 27°, 45 m 1 m Total	DW2B 7°, 30 m 1 m Total	DW2C -24°, 45 m 1 m Total
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 Total	DW3B 5°, 45 m 1 m Total	DW3B 5°, 45 m 1 m Total	DW3B 5°, 45 m 1 m Total	DW3C -29°, 75 m 1 m Total	DW4B 4°, 75 m 1 m Total	UW1B 171°, 72 m 1 m Total
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 Total	DW1B 10°, 15 m 1 m Total	DW1C -18°, 30 m 1 m Total	DW2A 27°, 45 m 1 m Total	DW2B 7°, 30 m 1 m Total	DW2C -24°, 45 m 1 m Total
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 Total	DW3B 5°, 45 m 1 m PM10	DW3B 5°, 45 m 1 m PM10	DW3B 5°, 45 m 1 m PM10	DW3C -29°, 75 m 1 m Total	DW4B 4°, 75 m 1 m Total	UW1B 171°, 72 m 1 m Total
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 2, Burn 3: 17:12 to 18:15 for a total burn period of 63 minutes

Boom 3, Burn 1: 08:46 to 09:25 for a total burn period of 39 minutes

Table 2 Average Aerosol Results Monitored by the RAM-1 During Burn Period (µg/m³)

Boom 3a, Burn 1

		DW1A 26°, 30 m 1 m Total	DW1B 10°, 15 m 1 m Total	DW1C -18°, 30 m 1 m Total	DW2A 27°, 45 m 1 m Total	DW2B 7°, 30 m 1 m Total	DW2C -24°, 45 m 1 m Total
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 Total	DW3B 5°, 45 m 1 m PM10	DW3B 5°, 45 m 1 m PM10	DW3B 5°, 45 m 1 m PM10	DW3C -29°, 75 m 1 m Total	DW4B 4°, 75 m 1 m Total	UW1B 171°, 72 m 1 m Total
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 Total	DW1B 10°, 15 m 1 m Total	DW1C -18°, 30 m 1 m Total	DW2A 27°, 45 m 1 m Total	DW2B 7°, 30 m 1 m Total	DW2C -24°, 45 m 1 m Total
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 Total	DW3B 5°, 45 m 1 m PM10	DW3B 5°, 45 m 1 m PM10	DW3B 5°, 45 m 1 m PM10	DW3C -29°, 75 m 1 m Total	DW4B 4°, 75 m 1 m Total	UW1B 171°, 72 m 1 m Total
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

Boom 3a, Burn 1: 07:54 to 10:07 for a total burn period of 133 minutes

Boom 4, Burn 1: 08:26 to 09:35 for a total burn period of 69 minutes

Table 2 Average Aerosol Results Monitored by the RAM-1 During Burn Period (µg/m³)

Boom 4, Burn 2

		DW1A 26°, 30 m 1 m Total	DW1B 10°, 15 m 1 m Total	DW1C -18°, 30 m 1 m Total	DW2A 27°, 45 m 1 m Total	DW2B 7°, 30 m 1 m Total	DW2C -24°, 45 m 1 m Total
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
	µg/m³ 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
	µg/m³ above Pre-Burn	8.4	242.4	250.3	-9.5	121.2	92.0

		DW3A 28°, 75 m 1 m Total	DW3B 5°, 45 m 1 m PM10	DW3B 5°, 45 m 1 m PM10	DW3B 5°, 45 m 1 m PM10	DW3C -29°, 75 m 1 m Total	DW4B 4°, 75 m 1 m Total	UW1B 171°, 72 m 1 m Total
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
	µg/m³ 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
	µg/m³ 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 Total	DW1B 10°, 15 m 1 m Total	DW1C -18°, 30 m 1 m Total	DW2A 27°, 45 m 1 m Total	DW2B 7°, 30 m 1 m Total	DW2C -24°, 45 m 1 m Total
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
	µg/m³ 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
	µg/m³ above Pre-Burn	-2.5	-3.8	722.8	-3.6	-6.5	580.5

		DW3A 28°, 75 m 1 m Total	DW3B 5°, 45 m 1 m PM10	DW3B 5°, 45 m 1 m PM10	DW3B 5°, 45 m 1 m PM10	DW3C -29°, 75 m 1 m Total	DW4B 4°, 75 m 1 m Total	UW1B 171°, 72 m 1 m Total
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
	µg/m³ 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
	µg/m³ above Pre-Burn	-11.3	0.0	-5.6	-4.9	226.2	0.0	-2.0

Boom 4, Burn 2: 10:37 to 11:40 for a total burn period of 63 minutes

Boom 4, Burn 3: 13:19 to 14:23 for a total burn period of 64 minutes

Table 2 Average Aerosol Results Monitored by the RAM-1 During Burn Period (µg/m³)

		Boom 5, Burn 1					
		DW1A 26°, 30 m 1 m Total	DW1B 10°, 15 m 1 m Total	DW1C -18°, 30 m 1 m Total	DW2A 27°, 45 m 1 m Total	DW2B 7°, 30 m 1 m Total	DW2C -24°, 45 m 1 m Total
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
	µg/m³ 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
	µg/m³ above Pre-Burn	27.5	109.1	20.8	14.8	69.8	19.8

		DW3A 28°, 75 m 1 m Total	DW3B 5°, 45 m 1 m PM10	DW3B 5°, 45 m 1 m PM10	DW3B 5°, 45 m 1 m PM10	DW3C -29°, 75 m 1 m Total	DW4B 4°, 75 m 1 m Total	UW1B 171°, 72 m 1 m Total
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
	µg/m³ 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
	µg/m³ above Pre-Burn	109.2	0.0	85.0	102.9	5.8	0.0	4.5

Boom 5, Burn 1: 12:51 to 13:53 for a total burn period of 62 minutes

Table 3 Total Aerosol Results Monitored by the DataRam During Burn Period (µg/m³)

		DW1A 26°, 30 m 1 m	DW1B 10°, 15 m 1 m	DW1C -18°, 30 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 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 1 m	DW2B 7°, 30 m 1 m	DW2C -24°, 45 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 UWupwin 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 4 PM-10 Aerosol Results Monitored by the DataRams During Burn Period (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	84.6	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		Boom 2, Burn 2	
	September 26, 97 (12:47 to 13:52 for 65 min)		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	60.0	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 pa DataRam # 1	USCG-moving 122-1009 m rom 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 5 PM-2.5 Aerosol Results Monitored by the DataRam During Burn Period (Ave µg/m³)

	DW1A 26°, 30 m	DW1B 10°, 15 m	DW1C -18°, 30 m	DW2B 7°, 30 m	DW3B # 1 5°, 45 m	DW3B # 2 5°, 45 m	DW3B # 3 5°, 45 m	UW1B 171°, 72 m
	Boom 4, Burn 3							
	October 01, 97 (13:19 to 14:23 for 64 min)							
Pre-burn 15 min	39.9	34.7	40.7	34.0	31.4	32.7	28.5	31.6
Pre-burn 30 min	42.8	37.1	43.1	36.6	34.1	35.7	31.3	34.3
Burn	32.8	170.6	620.0	185.4	156.2	157.2	167.5	23.8
Post-burn 15 min	38.3	33.4	546.4	31.5	28.4	28.7	27.7	30.7
	Boom 5, Burn 1							
	October 02, 97 (12:51 to 13:53 for 62 min)							
	DW1A 26°, 30 m	DW1B 10°, 15 m	DW1C -18°, 30 m	DW2B 7°, 30 m	DW3B # 1 5°, 45 m	DW3B # 2 5°, 45 m	DW3B # 3 5°, 45 m	
Pre-burn 15 min	11.6	9.5	13.9	8.1	3.0	6.0	9.5	
Pre-burn 30 min	12.1	11.6	14.4	8.9	3.1	6.0	9.7	
Burn	108.7	157.6	32.5	132.4	99.6	97.6	82.3	
Post-burn 15 min	43.3	79.7	27.6	67.3	56.7	70.6	50.1	

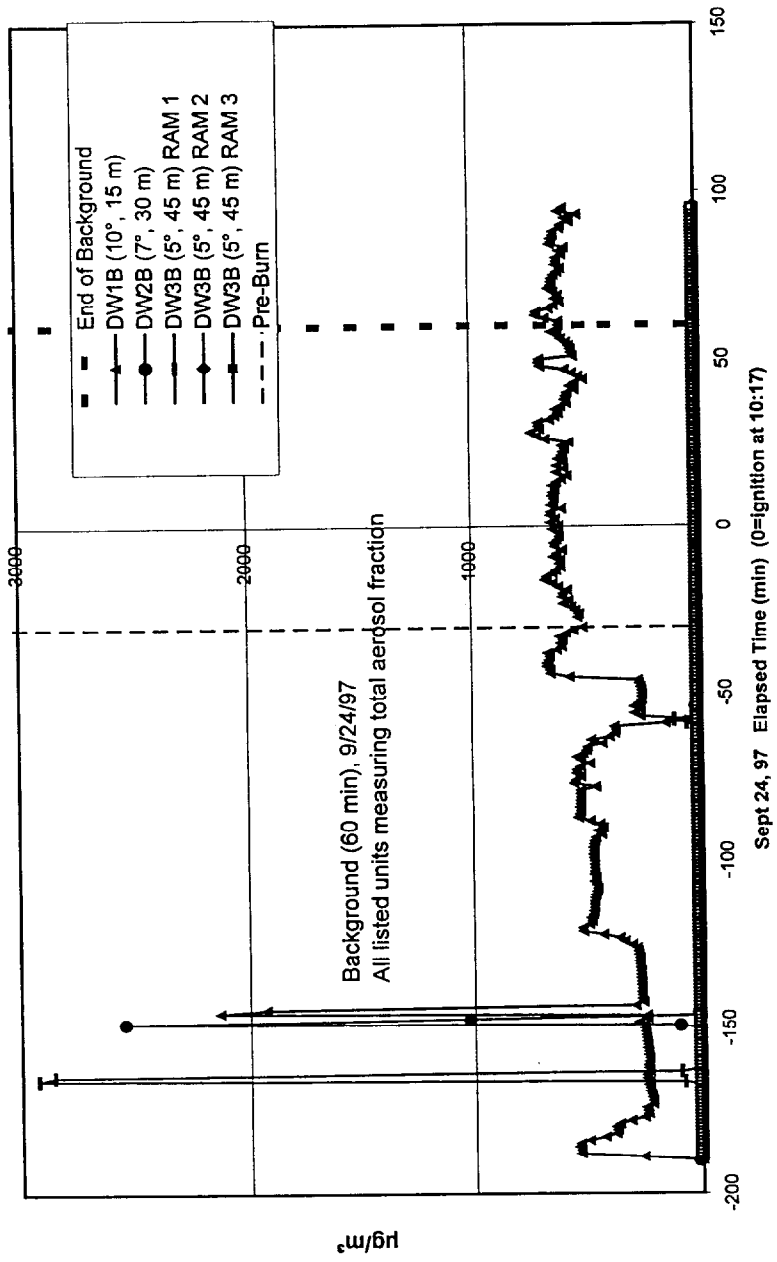

Figure 1 RAM-1, Concentration vs. Time

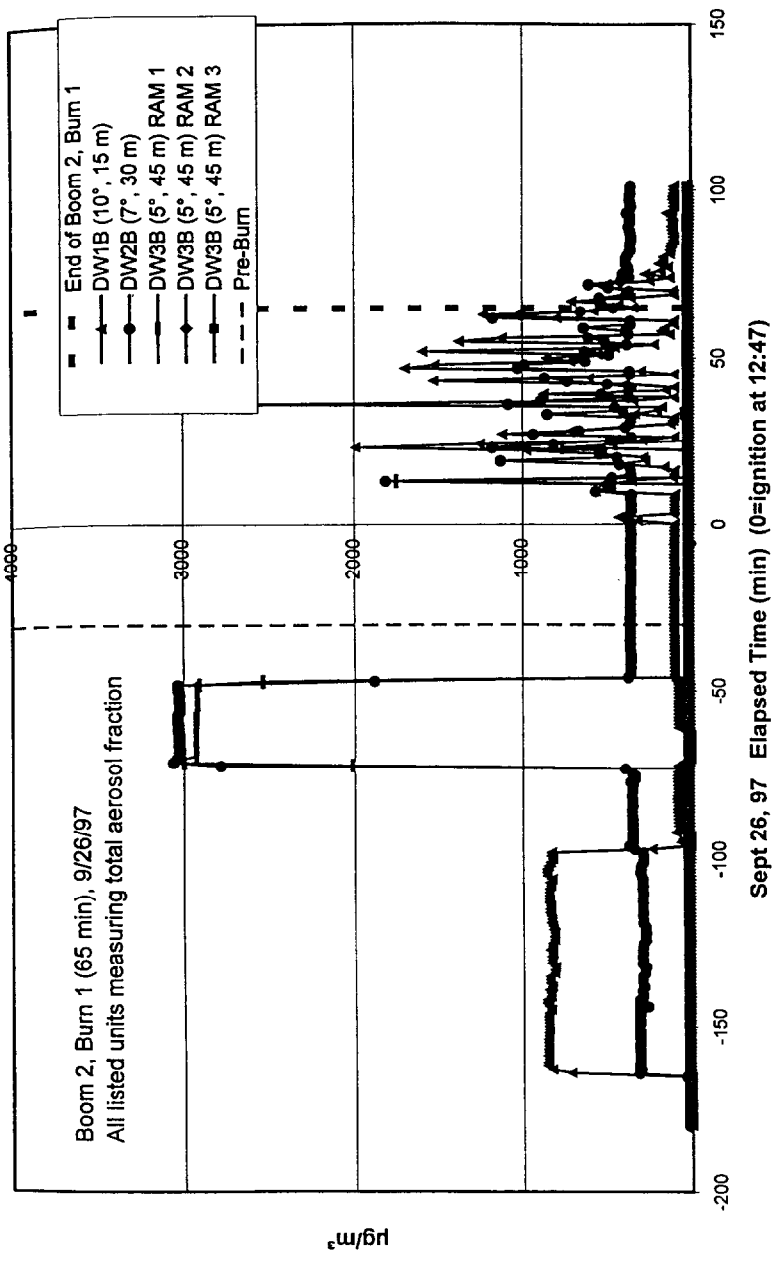

Figure 2 RAM-1, Concentration vs. Time

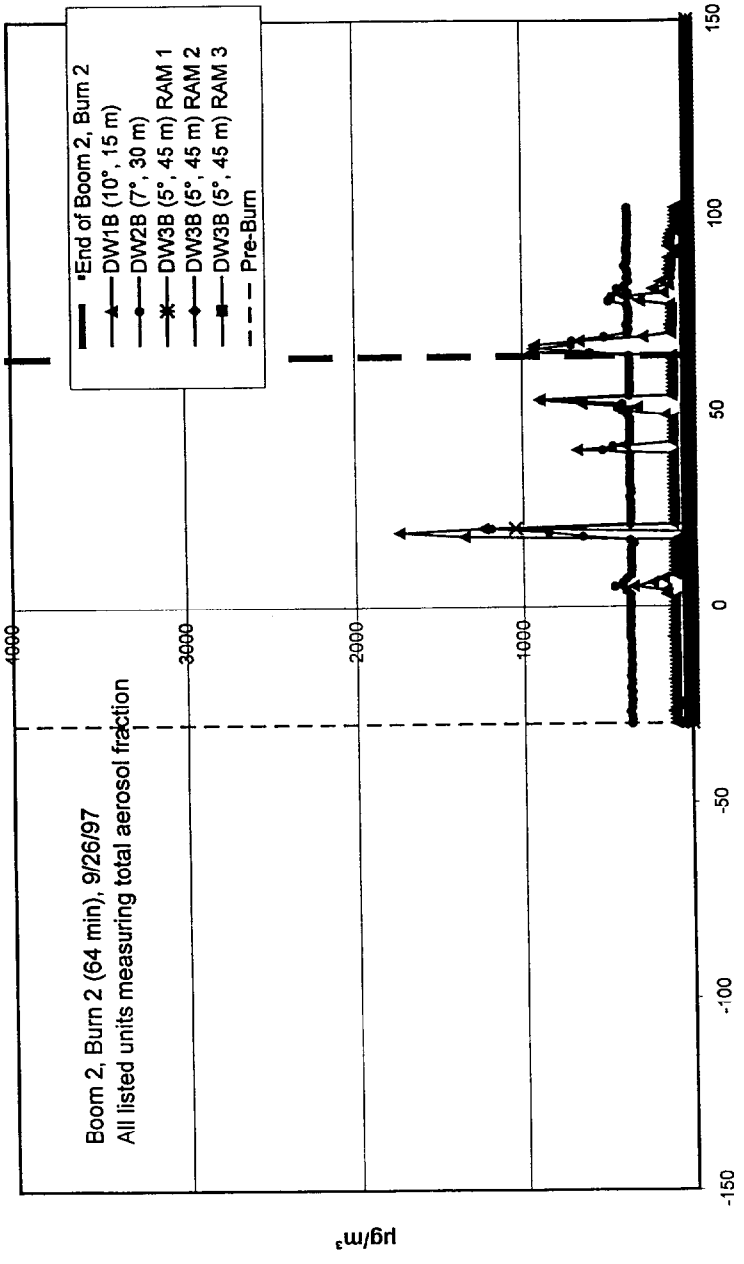

Figure 3 RAM-1, Concentration vs. Time

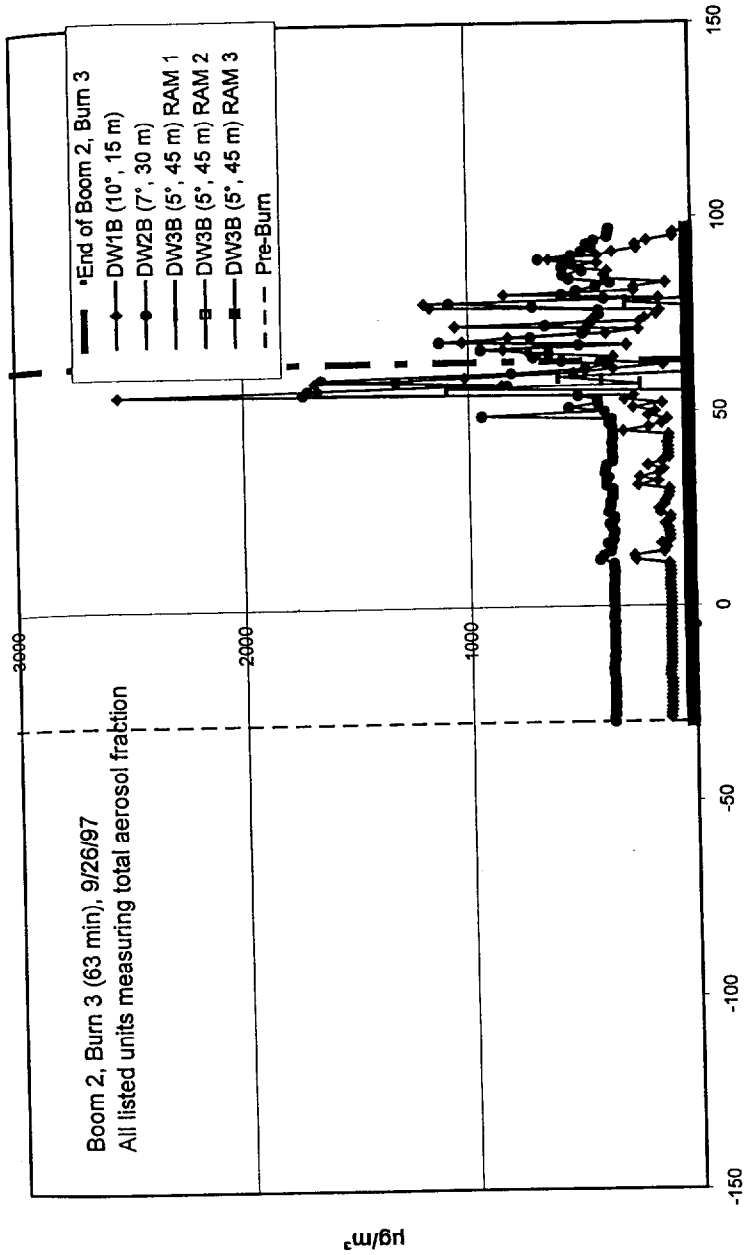

Figure 4 RAM-1, Concentration vs. Time

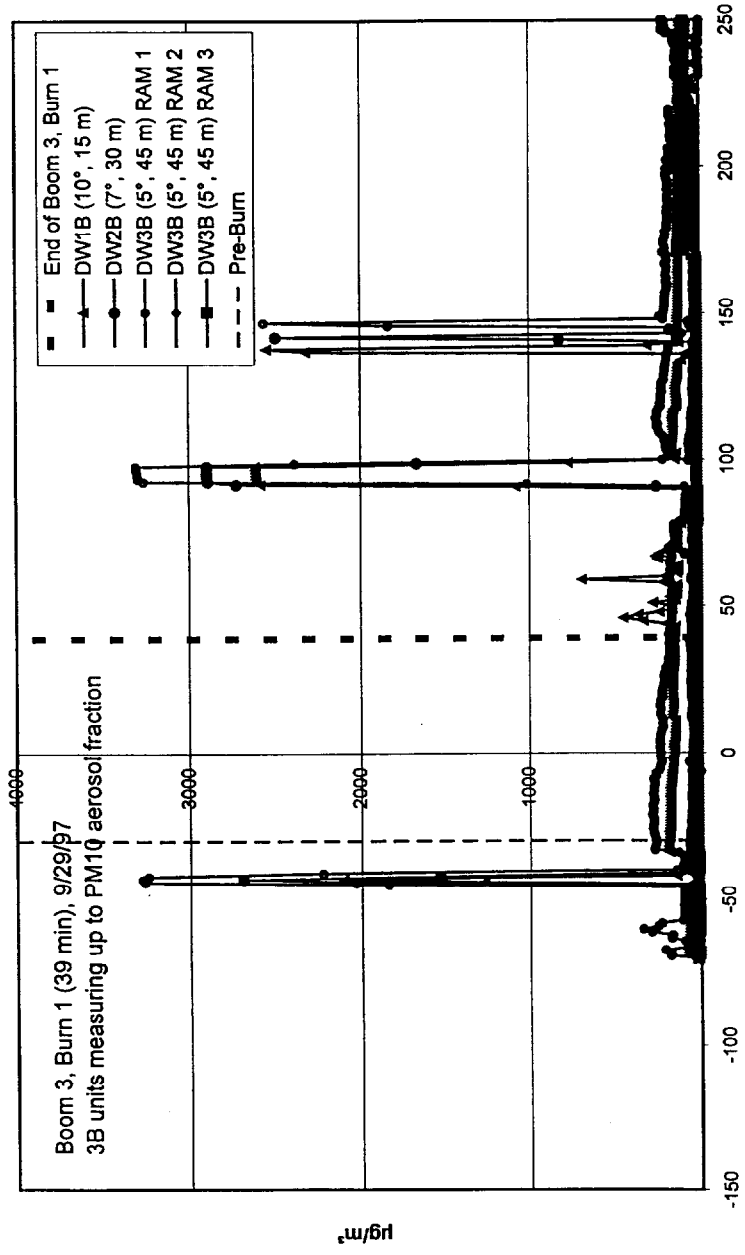

Figure 5 RAM-1, Concentration vs. Time

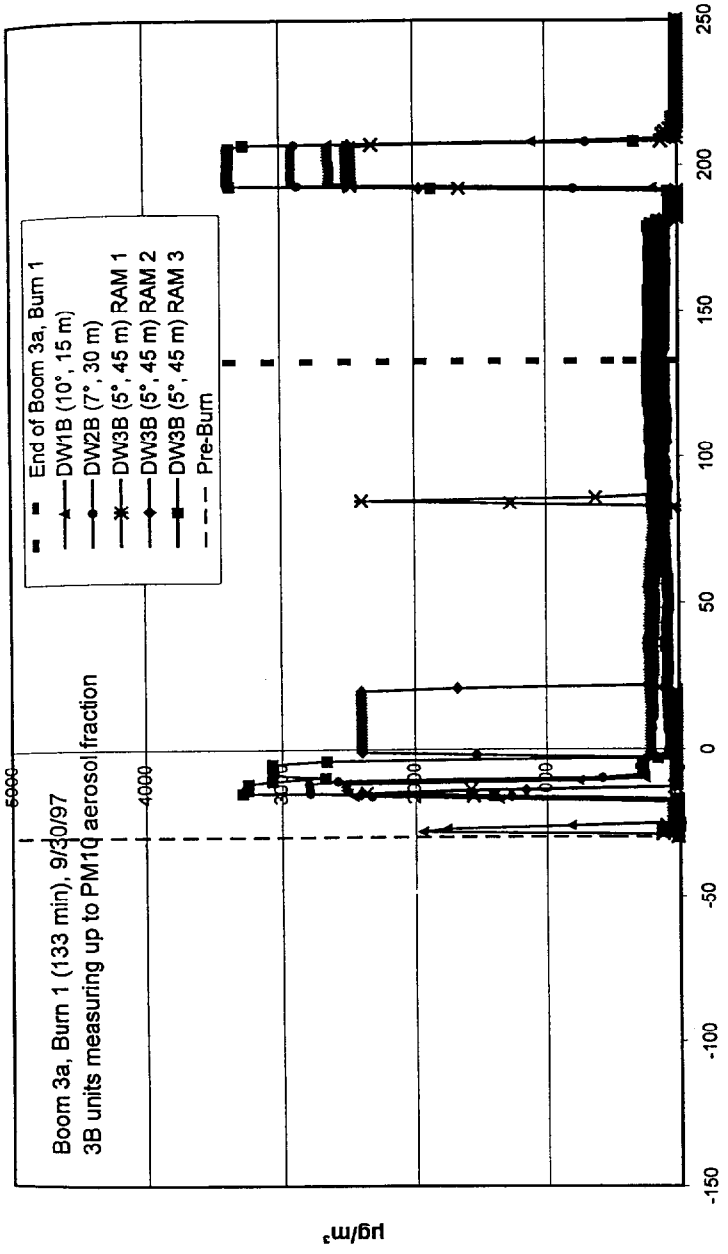

Figure 6 RAM-1, Concentration vs. Time

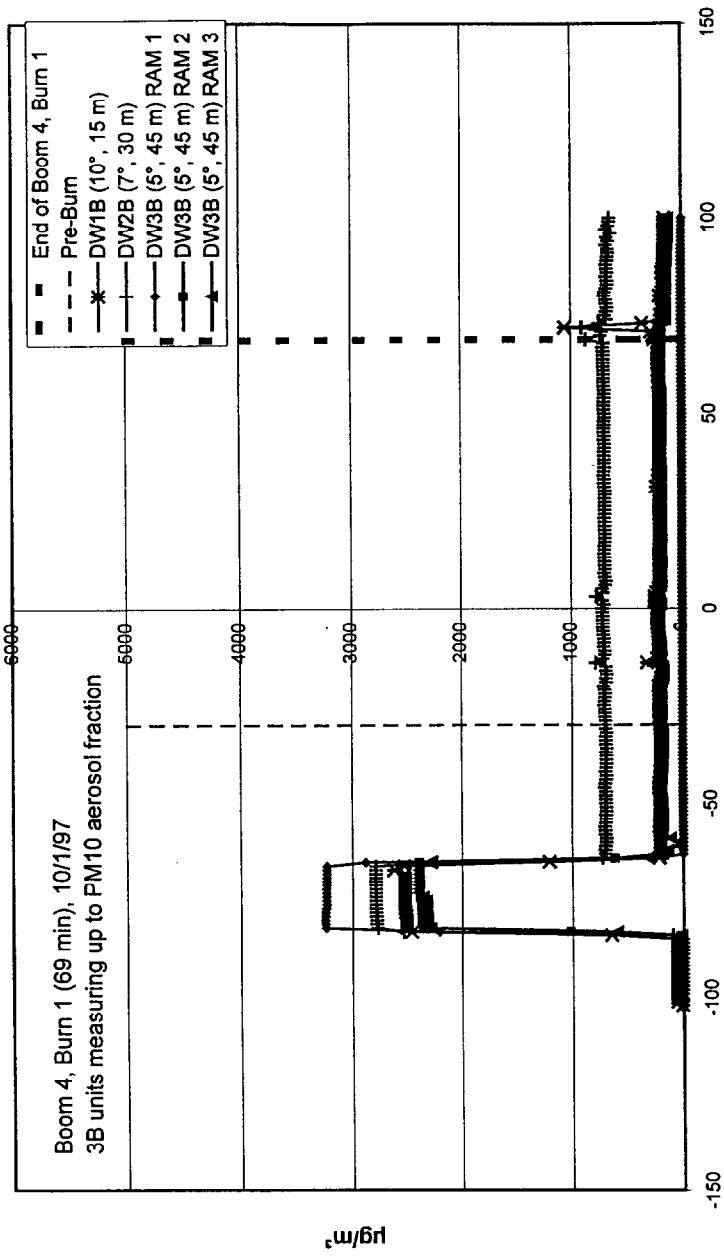

Figure 7 RAM-1, Concentration vs. Time

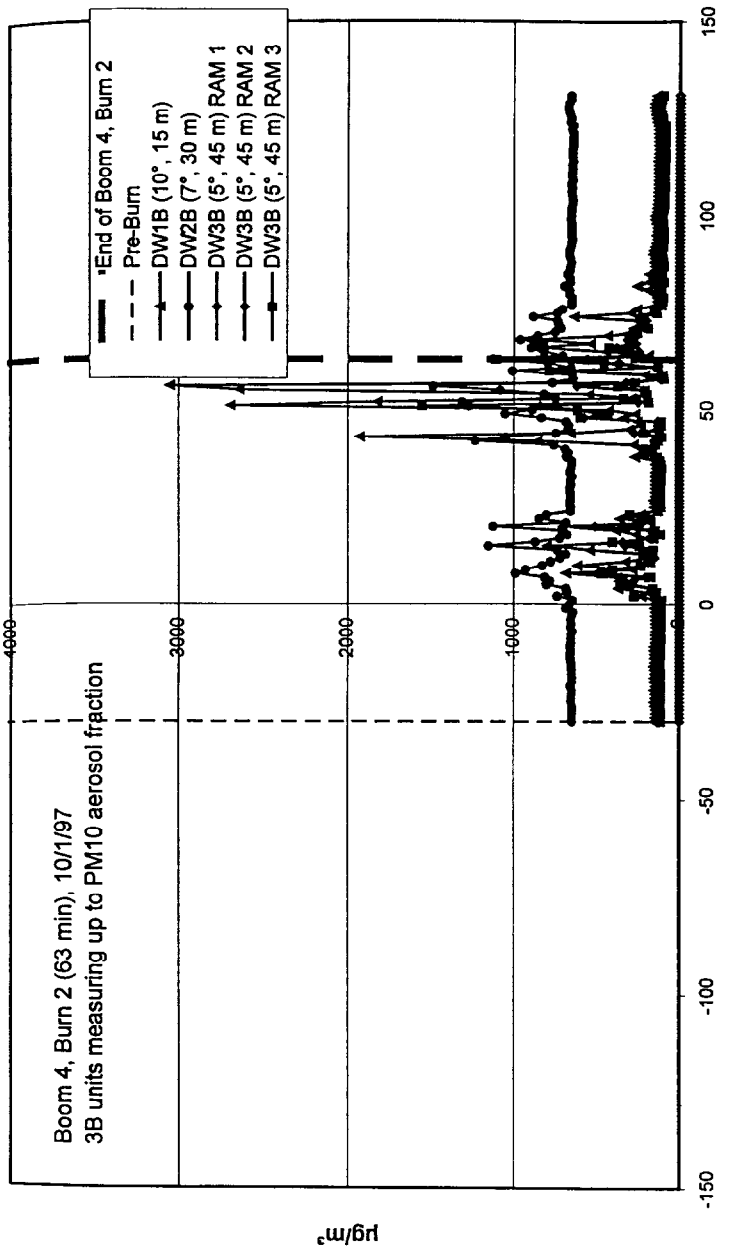

Figure 8 RAM-1, Concentration vs. Time

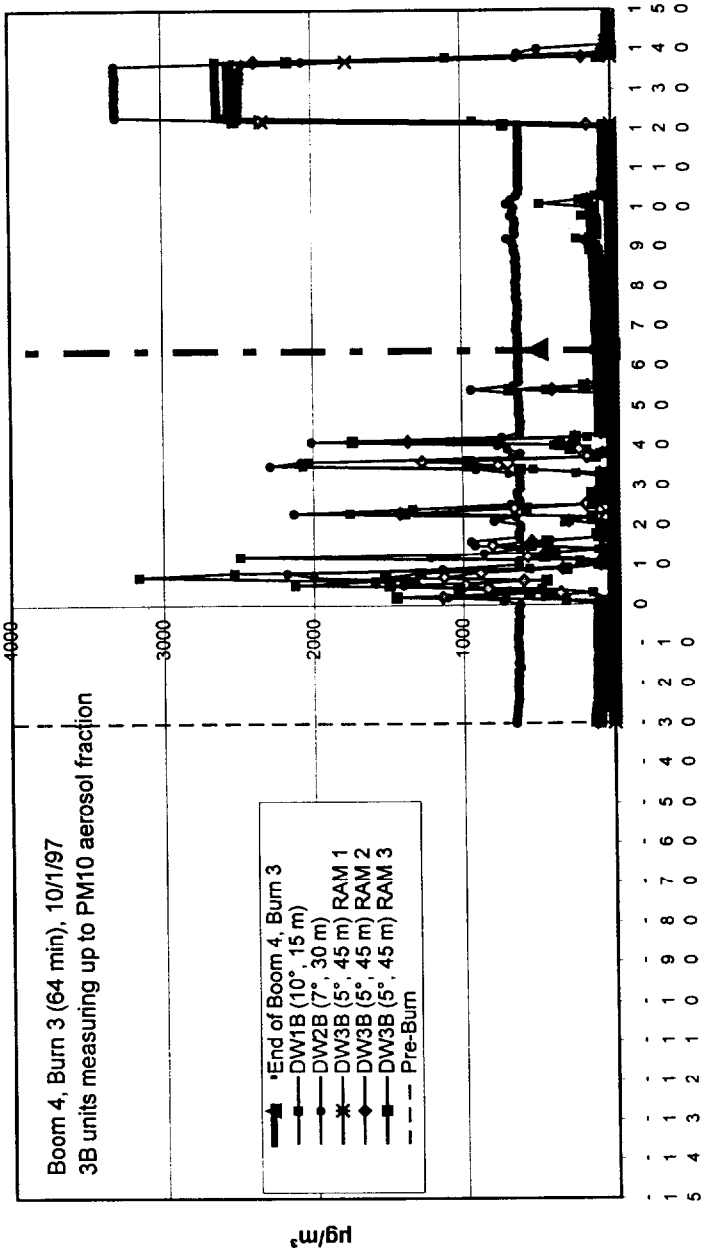

Figure 9 RAM-1, Concentration vs. Time

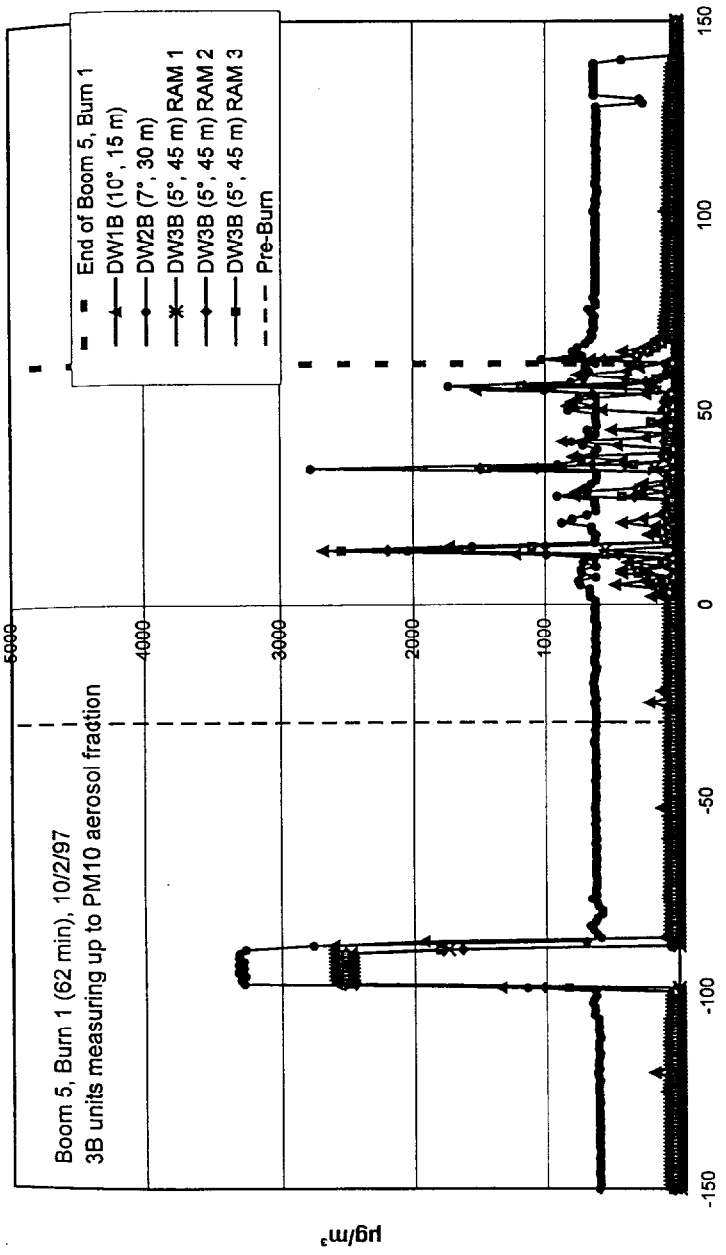

Figure 10 RAM-1, Concentration vs. Time

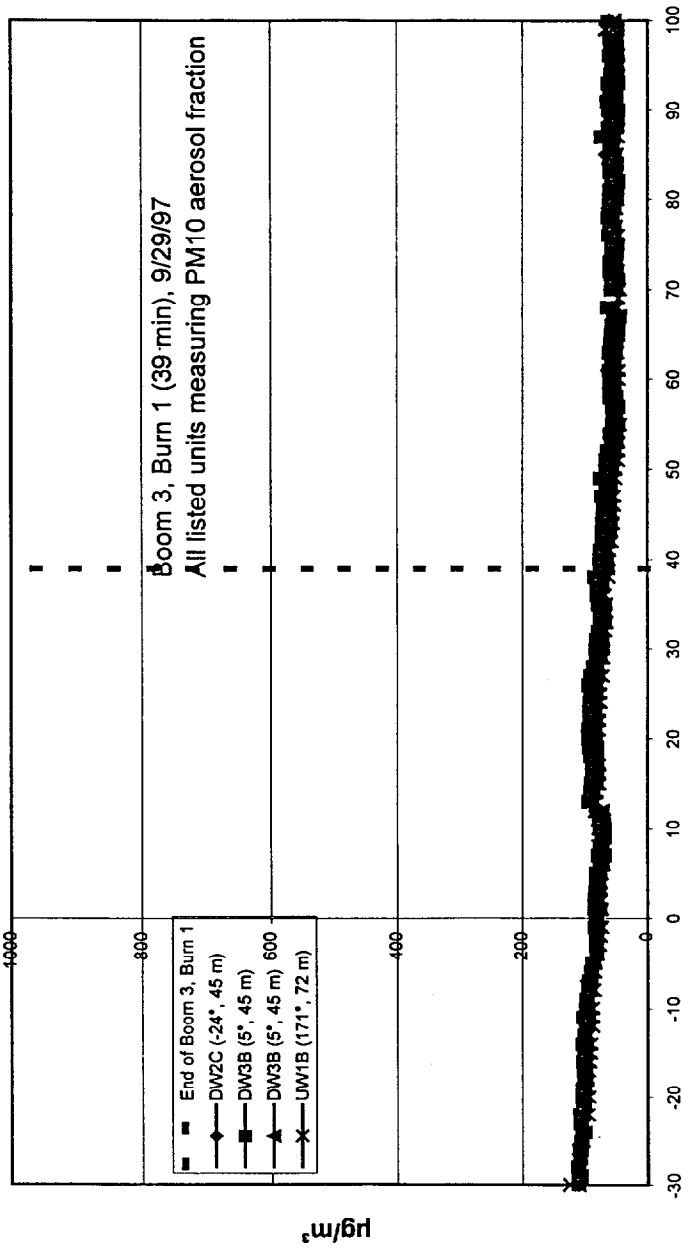

Figure 11 DataRAM, Concentration vs. Time

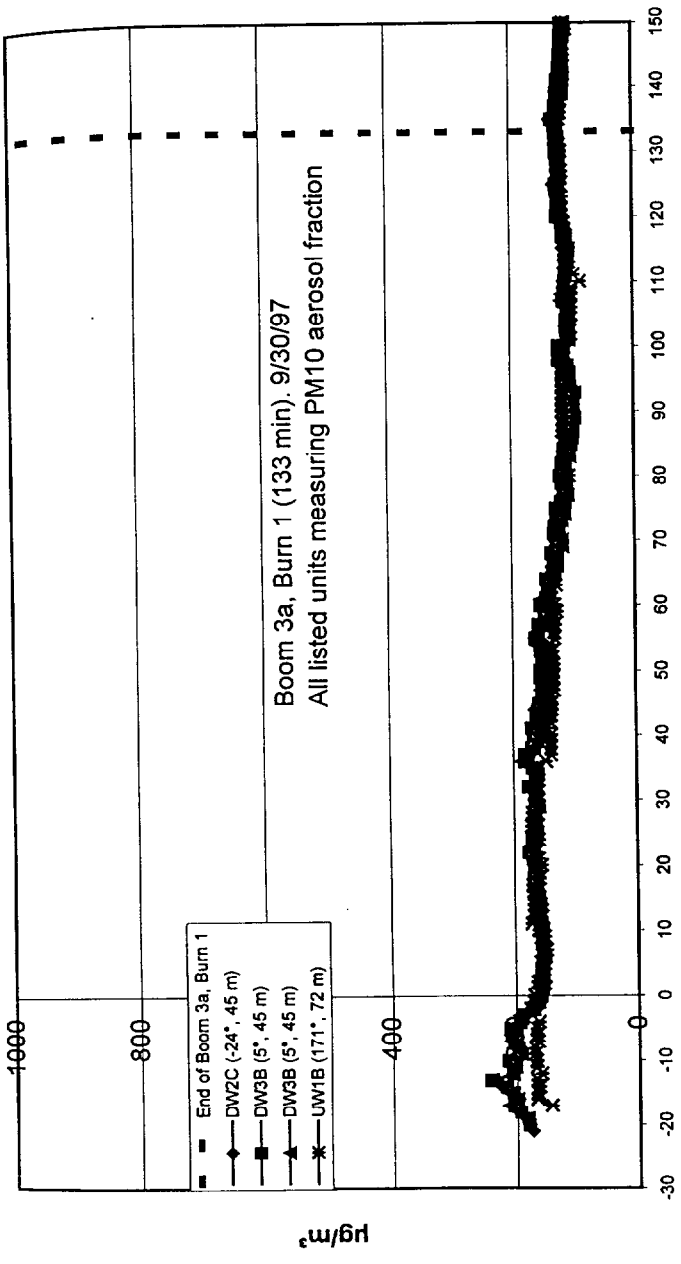

Figure 12 DataRAM, Concentration vs. Time

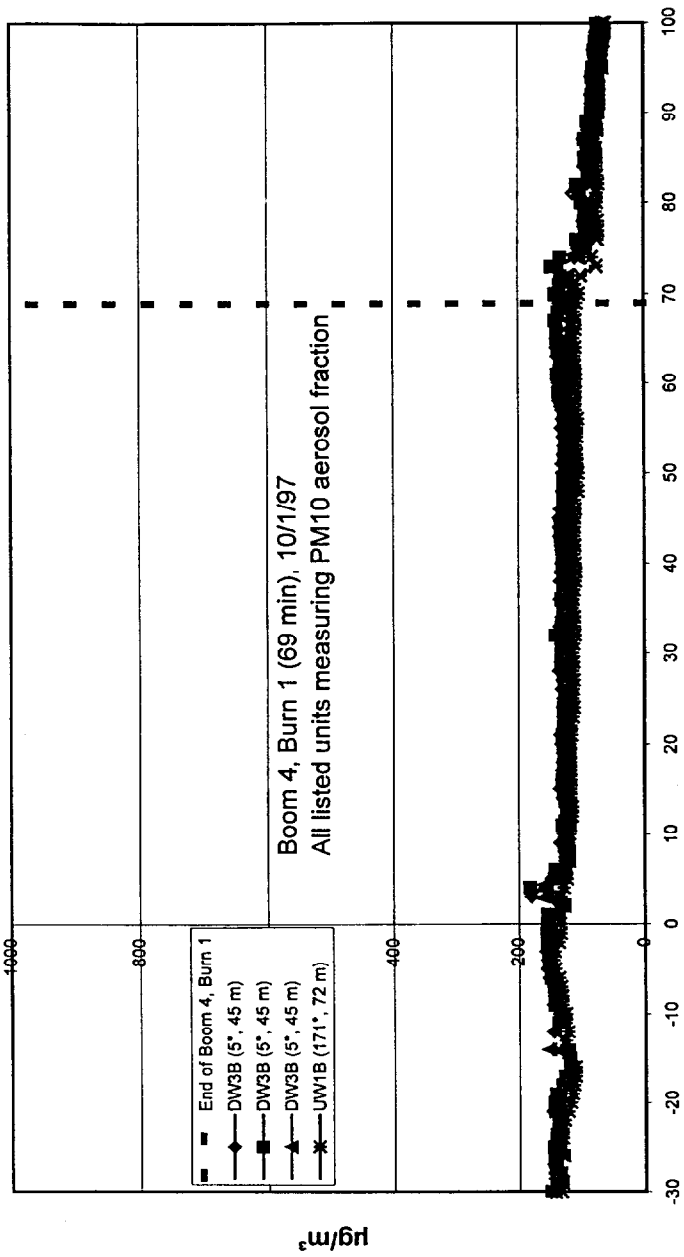

Figure 13 DataRAM, Concentration vs. Time

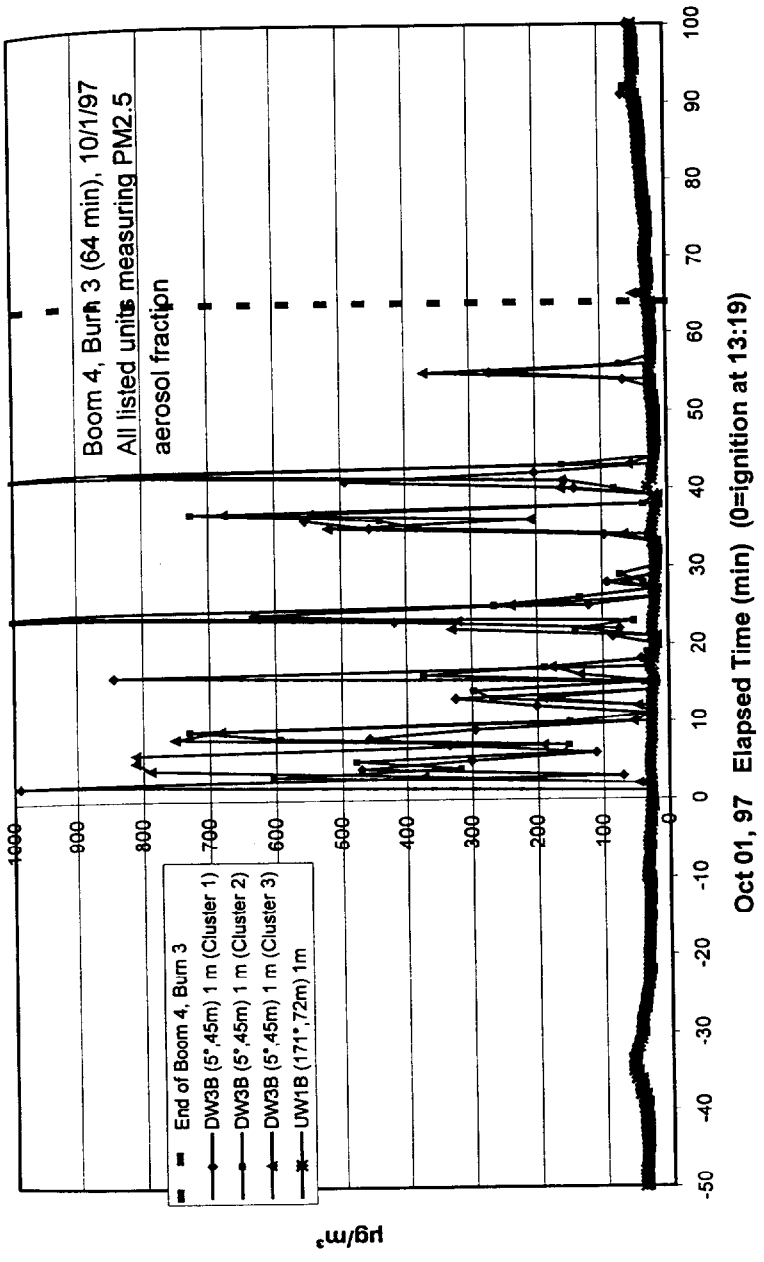

Figure 14 DataRAM, Concentration vs. Time

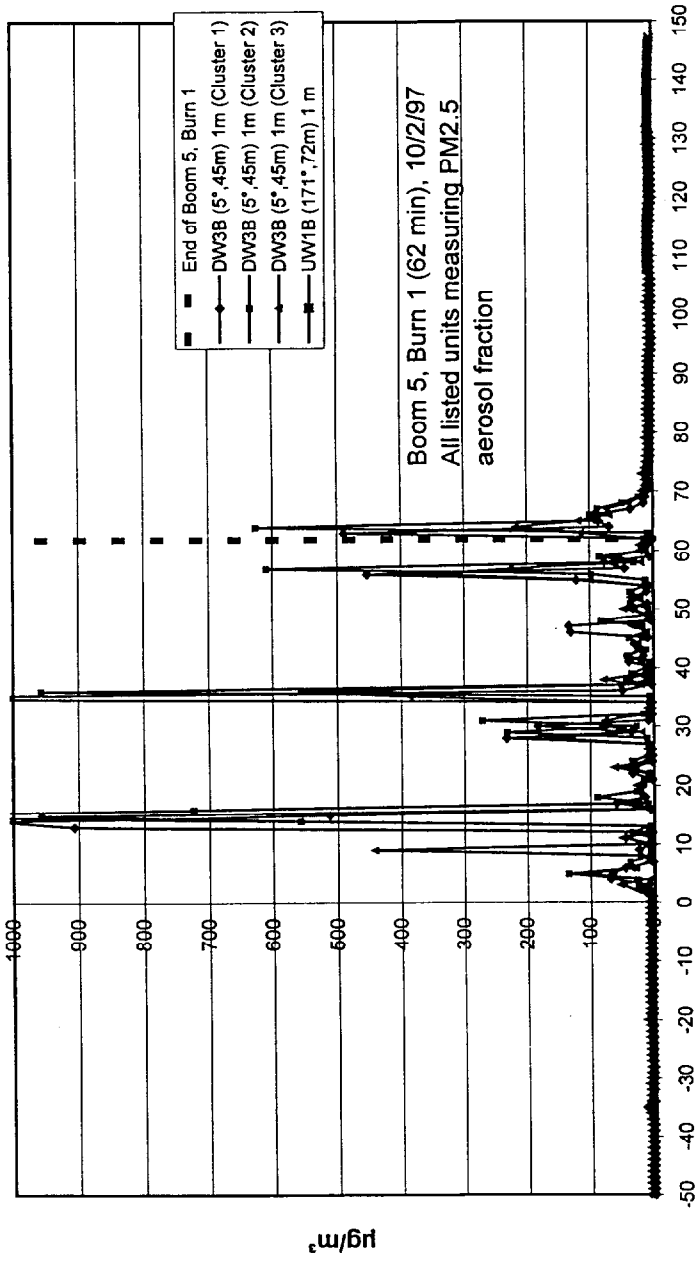

Figure 15 DataRAM, Concentration vs. Time

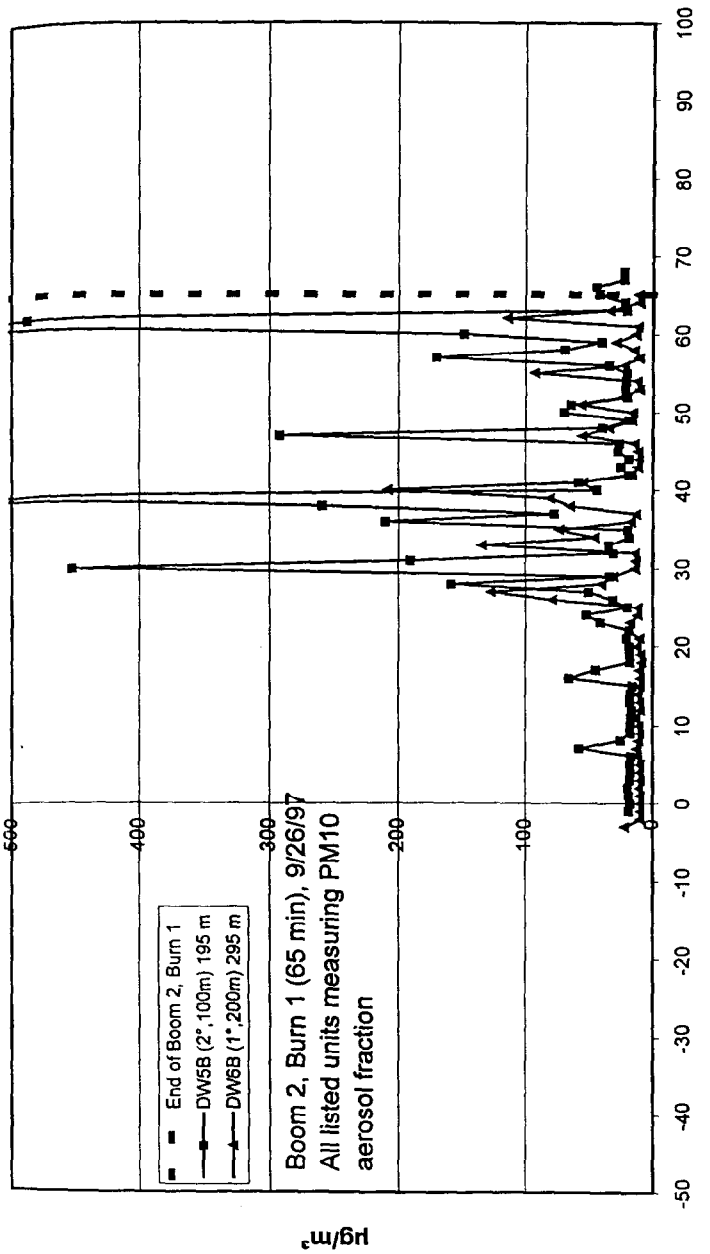

Figure 16 DataRAM, Concentration vs. Time

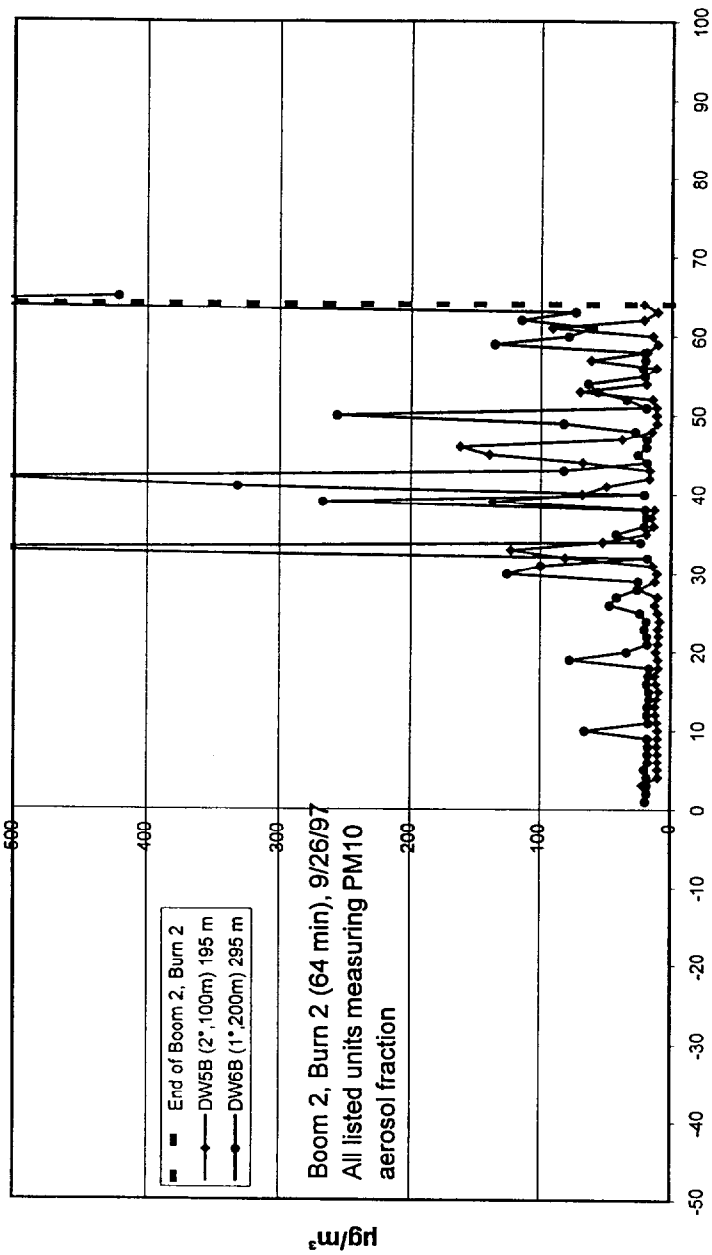

Figure 17 DataRAM, Concentration vs. Time

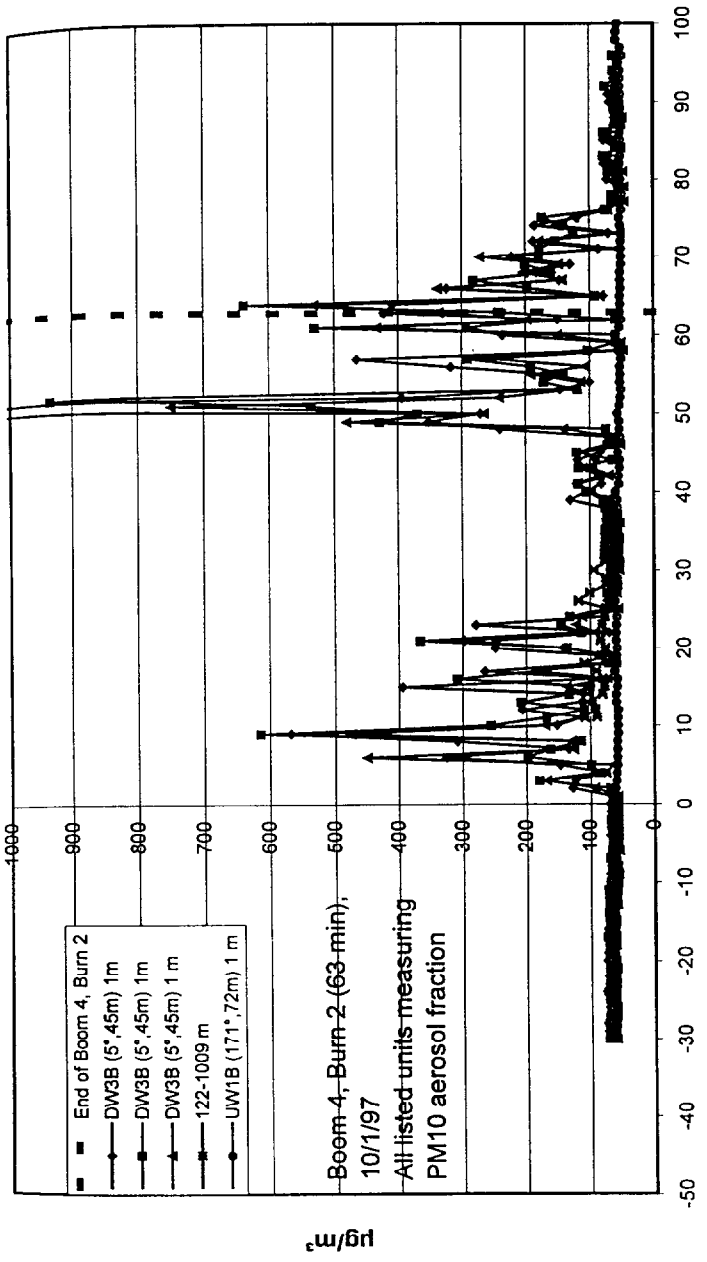

Figure 18 DataRAM, Concentration vs. Time

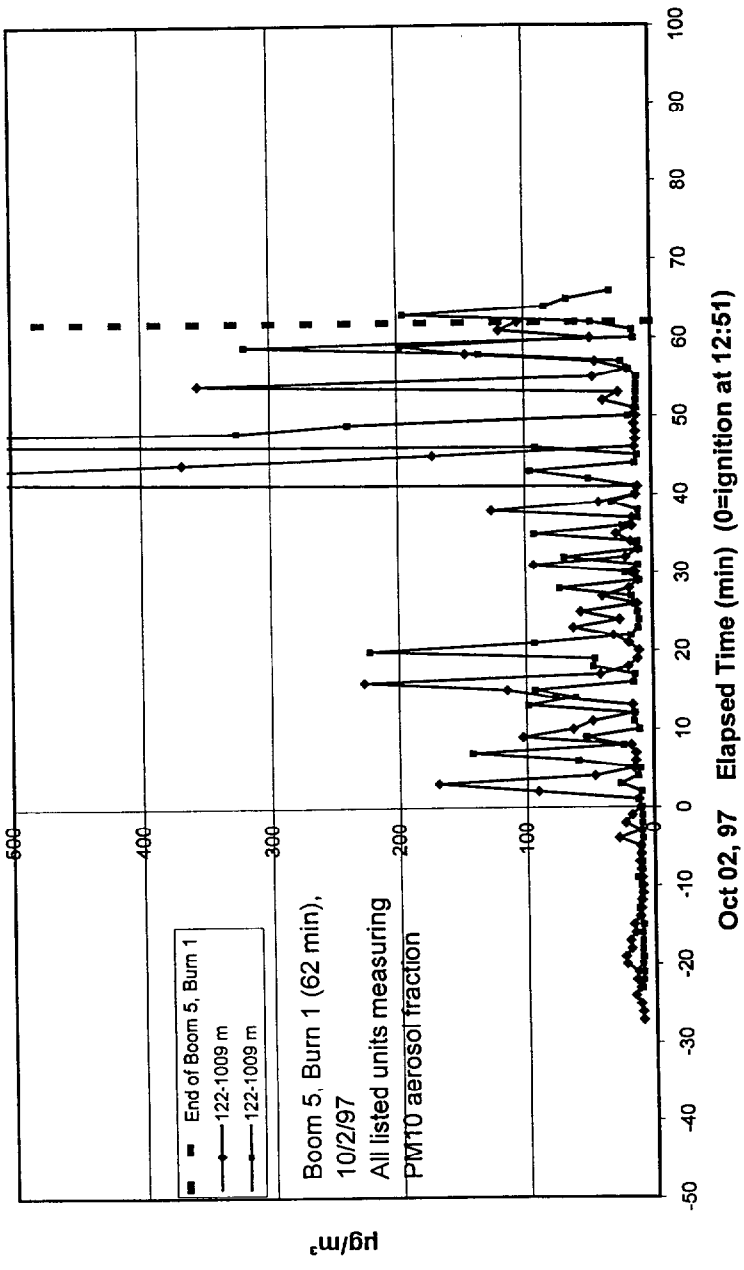

Figure 19 DataRAM, Concentration vs. Time

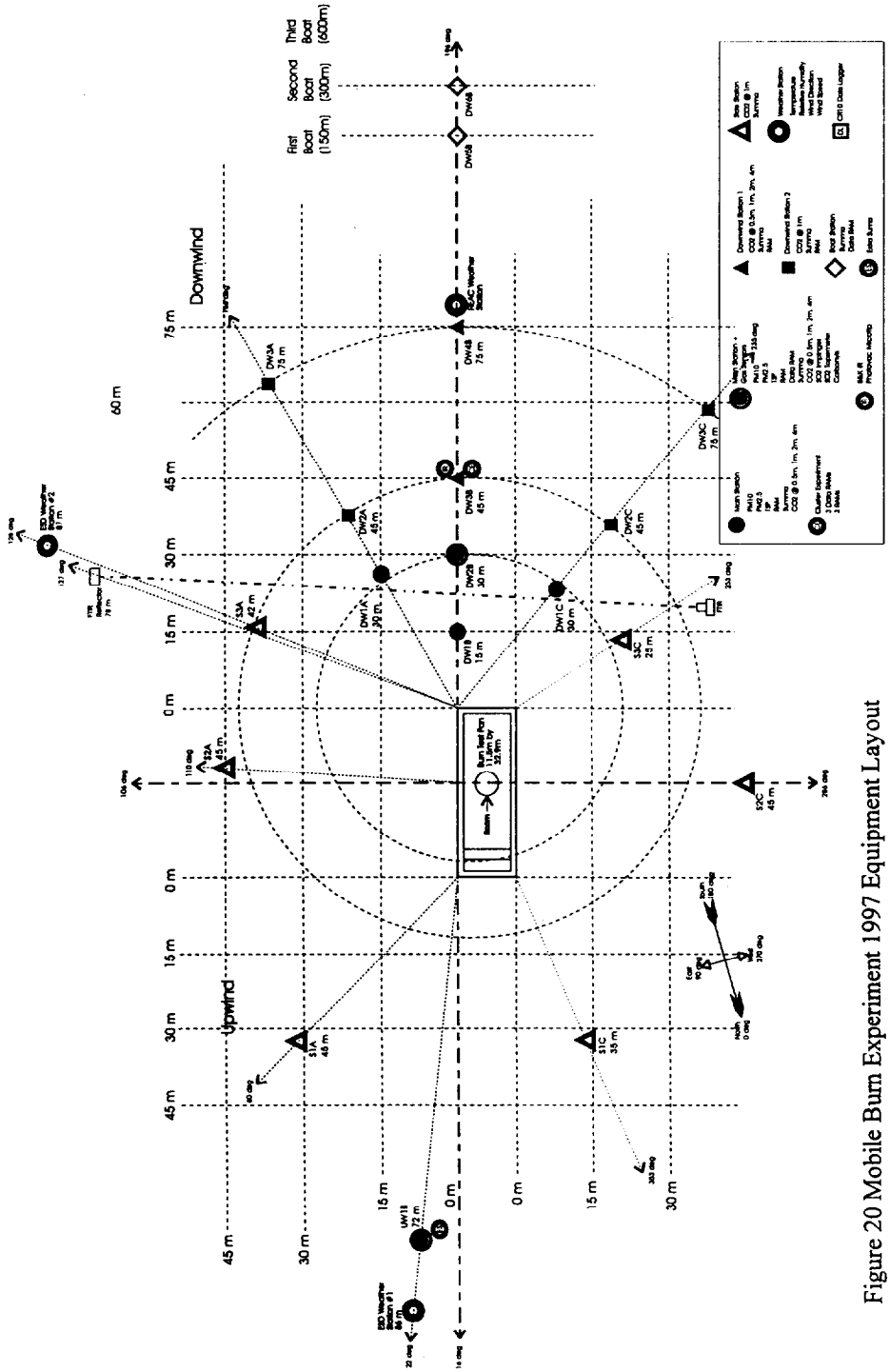

Figure 20 Mobile Burn Experiment 1997 Equipment Layout