Emissions From Mesoscale In-Situ Oil (Diesel)Fires: Gases, PAHs and VOCs from the Mobile 1997 Experiments

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Abstract

A series of twelve mesoscale burns were conducted in 1997 to assess fire-resistant booms and to study various aspects of diesel oil burning in situ. 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 seven side stations. Particulate samples in air were taken and analysed for Polycyclic Aromatic Hydrocarbons (PAHs). Water under the burns was analysed; small amounts of PAHs were found. The burn residue was analysed for PAHs as well. PAHs were at about the same concentration in the residue than in the starting oil, however there is a slight differential concentration increase in some higher molecular weight species in the residue. Combustion gases including carbon dioxide and carbon monoxide did not reach exposure level maximums. These gases were emitted over a broad area around the fire. Volatile organic compound (VOCs) emissions were measured in Summa canisters. Over 50 compounds were identified and quantified, most concentrations were too low to be considered a health risk.

1.0 Introduction

Eight 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.

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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 Little 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. In 1998, a paper reported on the analysis of the carbon dioxide and particulate material and on some of the instrumental methods (Fingas *et al.*, 1998; Lambert *et al.* 1998). This paper will report on the measurement of gases including additional measurements of carbon dioxide, VOCs and on the PAHs measured in the oil and residue. 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. A similar study was conducted in 1998 and emissions also measured during this series of experiments. These results will be reported in future papers.

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.

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. 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.

Methodology used for the real-time particulate monitoring is given in previous papers (Fingas *et al.*, 1998; Lambert *et al.* 1998). Results of the particulate monitoring are also reported in these papers. Table 3 summarizes the burns conducted and the conditions prevalent during these burns.

2.1 Oil, Residue and Water Samples for PAHs and Other Hydrocarbons

A 20 L (5 gallon) sample of the diesel fuel was collected from the fuel storage tank at the facility. Two fuel storage tanks were present at the site. The 10,000 US gallon storage tank housed the fuel employed for the test program. A small storage tank contained a second lot of the same fuel. The sample was collected from the smaller storage tank due to a lack of access to the 10,000 US gallon storage tank. The test protocol called for the continuous release of fuel to the tank. As such, a fuel sample was not collected prior to the initiation of the individual burns. The fuel was obtained from commercial ship fueling operators located in Mobile, Alabama. The sample was collected in a new 20 L metal can meeting specifications for the storage and transportation of fuel products (Industrial Compliance Centre, Mississauga ON).

A sample of the residue was collected in a new, clean, 250mL wide mouth glass jar with a Teflon lined cap (Fisher Scientific, Nepean ON). A total of four residue samples were collected. One sample was taken following the completion of each boom test series. No sample was collected upon the completion of the testing on the fifth and final boom. All residue samples were collected manually by skimming the residue from the surface of the water in the test tank. Little residue was present and the residue layer itself was thin. The bottle was filled 3/4 full, capped, labelled, and then stored/transported in a refrigerator (15 °C).

For analysis, approximately 0.4 gram of diesel fuel and residue was directly dissolved in hexane and made up to 5 mL with hexane. The concentrations of the diesel and residue samples were ~ 80 mg/mL. An aliquot containing 200 μL of oil solution was quantitatively transferred to the 3.0 g silica chromatographic column (which had been pre-conditioned with 20 mL hexane) for oil cleanup and fractionation. Additional 3 mL of hexane was applied to complete the transfer of oil. Hexane (12 mL) was used to elute saturate hydrocarbons, and 15 mL of 50% benzene in hexane (v/v) was used to elute aromatic hydrocarbons. Half of the hexane fraction (labeled F1) was used for analysis of total saturates, distribution of n-alkanes, isoprenoids including pristane and phytane, and of biomarker terpane and sterane compounds. Half of the 50% benzene fraction (labeled F2) was used for analysis of target petroleum-characteristic alkylated homologous PAHs and other EPA unsubstituted priority PAHs. The remaining halves of F1 and F2 were combined into a fraction (labeled F3) and used for the determination of total petroleum hydrocarbons (TPH). These three fractions were concentrated to appropriate volume using nitrogen blowndown in precalibrated centrifuge tubes. The fractions were then spiked with the appropriate internal standards and made up to accurate pre-injection volumes for GC analyses. The internal standard 5-α-androstane was added to F1 and F3 for determination of TPH, –alkanes and other interested individual aliphatic compounds;

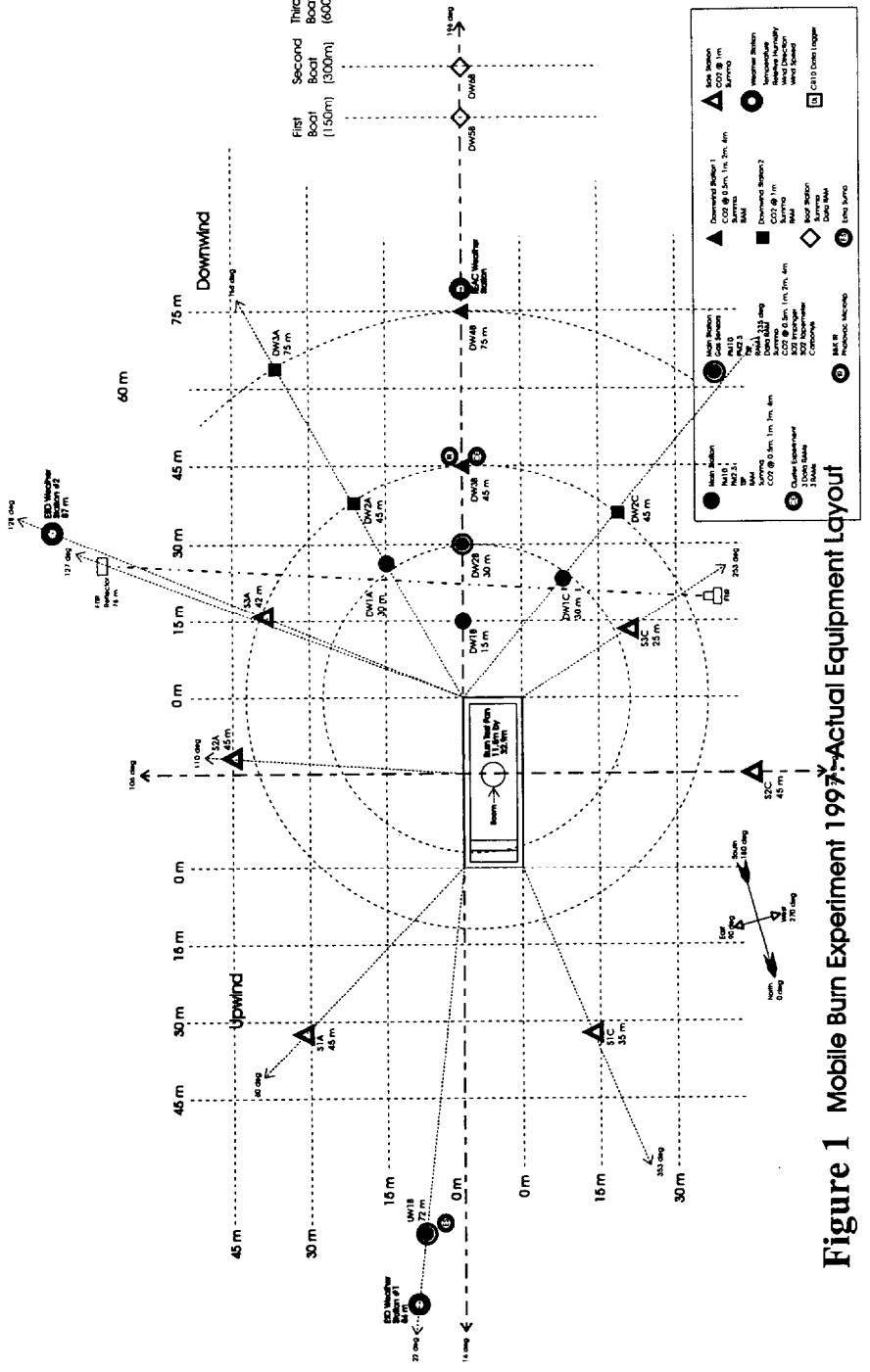

Figure 1 Mobile Burn Experiment 1997 - Actual Equipment Layout

Table 1 Summary of Equipment and Placement

Location / Equipment	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	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

Table 2 **Experimental Parameters and Weather Data**

	Start Fuelling hh:mm	Burn Time hh:mm	Burn Time (min)	Boom Area m^2	Oil Volume m^3
Background	No Fuel	10:17 to 11:17	60		No fuel
Boom1 Burn 1	9:28	9:40 to 10:45	65	10.8	2.4
Boom 1 Burn 2		12:23 to 13:27	64		2.3
Boom 1 Burn 3		14:34 to 15:36	62		2.3
Boom 2 Burn 1	12:40	12:47 to 13:52	65	14.8	3.2
Boom 2 Burn 2	14:52	14:59 to 16:03	64		3.2
Boom 2 Burn 3	17:04	17:12 to 18:15	63		3.2
Boom 3 Burn 1	8:38	8:46 to 9:25	39	13.5	1.8
Boom 3a Burn 1	7:47	7:54 to 10:07	133		3.1
Boom 4 Burn 1	8:18	8:26 to 9:35	69	11.8	2.6
Boom 4 Burn 2	10:29	10:37 to 11:40	63		2.5
Boom 4 Burn 3	13:11	13:19 tp 14:23	64		2.5
Boom 5 Burn 1	~12:43	12:51 to 13:53	62	20.3	4.4

Initial fuelling for 5 minutes to a depth of 18 mm before ignition
After ignition, fuel added at the rate it was consumed

Weather Data

	Mean Wind Speed	Mean Wind Direction	Mean Air Temperature	Barometer	Relative Humidity
	Knot	deg North	deg C	kPa	%
Boom 1 Burn 2	2<3<4	318<327<338	22<23<23	99<99<100	92<93<94
Boom 1 Burn 3	1<2<2	296<312<333	22<23<23	100<100<101	85<90<92
Boom 2 Burn 1	2<3<4	6<27<51	26<26<27	101<102<103	52<52<53
Boom 2 Burn 2	2<3<4	28<44<58	27<27<29	101<101<102	44<46<48
Boom 2 Burn 3	1<2<3	20<107<347	27<27<28	101<101<102	45<50<56
Boom 3 Burn 1	1<2<3	265<308<332	25<26<26	102<103<105	73<74<75
Boom 3a Burn 1	0<1<2	63<229<319	24<26<29	102<104<107	66<77<90
Boom 4 Burn 1	1<1<2	317<333<358	25<26<26	102<102<102	71<77<83
Boom 4 Burn 2	2<3<4	6<26<46	28<29<29	103<104<104	54<58<64
Boom 4 Burn 3	3<4<4	27<39<51	31<31<31	103<103<103	42<44<46
Boom 5 Burn 1	1<2<4	7<78<359	25<25<26	100<101<102	30<33<34

Weather results reported in "Min<Ave<Max" format for the Burn Period

the IS d_{14}-terphenyl was added to F2 for quantitation of PAH compounds; and the IS C_{30} $\beta\beta$ hopane was added to F1 for determination of biomarker compounds.

Prior to sample analysis, the instrument was calibrated with standard calibration mixture solutions. A 5-point calibration curve that confirmed the linear range of the analysis was established. The relative response factors (RRF) for each hydrocarbon component was calculated relative to the internal standard.

Two 1 L water samples were collected from the tank shortly after the tank was filled with water and prior to the commencement of the test program. This sample has been named the preburn sample. As a minimum, a 1 L sample of water was collected from the tank following the final burn test for four of the five booms which were evaluated. A single litre of water sample was collected following the testing of the first boom. Two 1 L samples were obtained following the completion of the test series for the subsequent booms. No sample was collected upon the completion of the testing on the fifth and final boom. In total five water samples were collected. All water samples were manually collected at a depth of approximately 10 cm (4") below the surface for the water. The sample was collected and stored in a new, clean, 1 L amber Boston round bottle with a Teflon lined cap (Fisher Scientific, Nepean ON). The capped bottle was inserted into the water, opened, allowed to fill such that there was no head space in the bottle, recapped, removed from beneath the water, labelled, and stored/transported in a refrigerator at (15°C). The sampling location was generally about the centre of the tank and the sample was collected during preparations to remove the boom.

Water sample extraction was conducted as follows: (1) each water sample was spiked with 100 µL PAH surrogate standards (four d_{10}- and d_{12}-PAHs, 10 ppm each), and 100 µL 200 ppm o-terphenyl in 1.0 mL of acetone, and sat for 15 minutes; (2) each water sample was then subsequently extracted 3 times with methylene chloride (200, 100, and100 mL DCM) for approximate 3 min each time; (3) the combined extract was dried by passing through the Na_2SO_4 layer and then concentrated to appropriate volume by rotary evaporation; (4) the solvent DCM was exchanged to hexane using the solvent exchange technique; (5) the extract was finally blown down with N_2 and made up to accurate 1.0 mL. The sample was analyzed in the same manner as noted for the oil and residue.

2.2 Gases Using Long-Path Infrared

The OP-FTIR spectrometer was used and was capable of detecting carbon dioxide (CO_2), carbon monoxide (CO), n-octane, iso-octane and benzene, toluene, ethyl benzene, and xylenes (BTEX) in air. The OP-FTIR spectrometer, in a unistatic configuration, has the transmitter and receiver collocated within the unit. A corner-cube array retroreflector is used to return the transmitted infrared beam back along the beam path to the receiver. With an open-path system, the total contaminant burden is measured within the finite cross-section of the light beam along the entire length of the beam path. The contaminant burden is then normalized to a path length of one meter. This gives a path-integrated concentration of parts per million-meters (ppm-m).

The OP-FTIR and retroreflector were positioned so that the beam path was located along the predominately downwind side of the burn area. The one-way pathlength was 120 meters, located approximately 22 meters south of the burn test pan, between monitoring stations DW1B and DW2B. Results are usually given in

concentrations determined by dividing the path-integrated concentrations by the 120 meter path length to give an average concentration, along the entire path, in ppm values.

The minimum detection limit (MDL) for each compound is determined every run by the analysis software. For each target compound, the MDLs were based on twice the concentration residual of the classical least squares fit algorithm for the specified analysis region. The number of data runs varied for each of the burns monitored depending on how long it took the fire to extinguish, and how closely successive burns were spaced. When time permitted, monitoring continued an hour past the end of the burn. The average number of runs per burn was 41. Benzene was detected during the daily accuracy runs, where it was introduced into the instrument's 0.15m internal quality assurance (QA) cell. Possible interferences were humidity, and particulates in the plume as smoke passed directly through the beam, which could increase MDLs. On-site diesel generators could have contributed to the contaminant burden passing through the beam, increasing the detected concentrations. The nearest generator to the beam path was approximately 75 meters to the south.

Quality assurance/quality control (QA/QC) measures were instituted daily. A sulfur hexafluoride (SF_6) gas standard at a concentration of 55 ppm was introduced into the instrument's internal 0.15 m QA cell. The SF_6 was trapped in the cell during all data collection runs to provide a measure of FTIR system functionality and a measure of instrument precision. Due to the possibility of pressurizing the internal QA cell when trapping the precision gas, any time the cell was refilled with SF_6 a new precision set was started.

Benzene was the gas chosen to challenge the system's accuracy. An accuracy data run was collected at the start and end of each day. Benzene was allowed to flow through the instrument's internal QA cell so as not to pressurize the cell, affecting the concentration. Percent accuracy is determined by the difference between the observed and the actual concentrations divided by the actual and multiplied by 100. The overall project accuracy was 17.8 percent, accuracy values should be below 20 percent.

The overall performance of the OP-FTIR was satisfactory. The apparatus is capable of quantifying carbon dioxide (CO_2), carbon monoxide (CO), benzene, toluene, ethyl benzene, and xylenes (BTEX), iso-octane, n-octane and the tracer gas carbon tetrafluoride. No benzene, toluene, or ortho-, meta-, and para-xylenes were detected above the MDL during any of the data runs. Ethyl benzene and iso-octane were only detected during periods of fueling the boom, prior to ignition of the oil.

2.3 Carbonyls

To obtain a sample for analysis, a Gilian Aircon2 pump (Gilian Instrument Corp, West Caldwell NJ) was used to draw an air sample through a DNPH (2,4 dinitrophenylhydrazine) silica cartridge (Millipore Corporation, Milford MA) attached via Tygon tubing to the pump. The cartridge is a Waters Sep-pak containing 350 mg of silica coated with 1.0 mg DNPH. The flow rate of the pump was set at 1 L/min with an air volume of approximately 60 L passing through the cartridge over the hour long burn. The flow rate of the pump was calibrated on a regular basis. Trip, field and calibration blank samples were collected. The sampling apparatus was manually turned on and off at times corresponding to the start and end of the individual burn tests. Cartridges were kept frozen prior to use and the sample was placed in an amber vial and replaced into the freezer until analyzed. The cartridges

were analyzed at Environment Canada's, Environmental Technology Centre by for aldehydes and ketones using a Hewlett-Packard 1090 High Pressure Liquid Chromatograph (HPLC).

2.4 VOCs in Summa Canisters

To monitor the VOC concentration in air an array of 6L, stainless-steel SUMMA canisters were located about the burn pan. The canisters were pre-evacuated to 0.05 mm of Hg. The flow controller (adjustable restricted orifice) is adjusted to known flow rate to collect approximately 4.5 Litres of sample (volume after which the intake of the canister is no longer linear). Summa canisters placed at the five main stations were changed out with each burn. A flow rate of 75 cc/min was established to achieve the desired volume of 4.5 L over the hour long burn. Sample canisters at the side stations had a flow rate of 25 cc/min and remained at a station for a total of three 1 hour burns. The sampling orifice were opened and closed manually in co-ordination with the start and end of each burn.

An aliquot of the air sample is withdrawn from the canister, the water is removed and the VOCs is concentrated prior to injection onto the head of a GC capillary column. The major components of this system include two electronic flow controllers (FC260 with RO-32 control box, Tylan Corp., Torrance, Ca), a Nafion PermaPure dryer, a six port Valco™ gas valve, a cryogenic preconcentration trap and a sub-atmospheric temperature programmable gas chromatograph equipped with a quadruple mass selective detector (GC-MSD).

Canisters which are returned from the field at atmospheric or sub-atmospheric pressures following sampling must be pressurized prior to analysis. The canister is filled to approximately 30 psi with clean humidified air and a dilution factor is calculated from a previously obtained calibration curve. All lines are evacuated and purged with clean humidified air prior to filling. A flow rate of approximately 200 mL/min. is maintained by an electronic mass flow controller and verified with a Gilian™ soap-film bubble flowmeter. A certified clean canister is also filled and serves as a blank.

The volume of sample aliquots is adjusted so that target compounds fall within the analytical system calibration range of each of the target compounds. This varies from 1 mL to 500 mL depending on the initial concentration of the sample. A sample loop is used for 1 mL and 10 mL aliquots and a gas-tight syringe is used for 20 mL to 200 mL aliquots. Larger aliquots (250 mL to 1000 mL) are withdrawn from the cylinder for 10, 15, 20 or 30 minutes at a constant flow of 25 mL/min. The flow rate is maintained by electronic mass flow controllers and verified with a Gilian™ soap-film bubble flowmeter.

A Nafion PermaPure™ dryer is used to prevent blockage of the trap and/or capillary column by ice formation at reduced temperature. To prevent excessive moisture build-up and memory effects the dryer is heated to 100 °C and purged with clean dry air for 20 minutes following each sample injection.

2.5 CO_2 in Summa Canisters

The Summa canisters used for VOCs were also used for carbon dioxide analysis. A Hewlett Packard 5890 Gas Chromatograph with microvolume TCD was used with Hewlett Packard 3365 DOS ChemStation software. The injection was via a Valco 6-port gas sampling valve with 1.0 mL loop in heated enclosure. The column

was a 7 'x 0.125" Porapak R (80/100) with valve injection directly on column. The valve enclosure was maintained at 80°C, the detector block 200°C and the oven temperature started at 25°C, hold 2.5 min then ramped 25°C/min to 180°C, hold 2.8 min. The carrier was Helium at 40.0 mL/min. The TCD Reference was Helium at 60.0 mL/min.

The oven temperature program is primarily used to remove heavier compounds and water from the column before the next injection. The CO_2 peak emerges during the initial isothermal segment. The TCD was calibrated by injection of a known concentration of CO_2 in N_2 (4758 ppmv) obtained from Matheson Gas Products. To verify calibration linearity the CO_2 standard was dynamically diluted with CO_2 free N_2 using a master/slave mass flow controller system and various dilutions were analyzed in the same manner as the samples. A small metal bellows vacuum pump was used to draw the sample into the loop from a TEDLAR bag. The pressure inside the loop was allowed to equilibrate with ambient pressure before injection onto the column. Since the canisters supplied were under vacuum, a gauge was used to measure the pressure inside the loop when attached to the canister. A pressure correction curve was prepared to correct the analysis results for reduced pressure. Both the ambient calibration curve and the pressure correction curve are given. Any canister with a pressure below 20" Hg could not be analyzed due to the pumping capacity of the pump being used. For canisters with very low pressures (<10" Hg), the analysis is probably more representative of the gas used to clean and flush the canister than the sample taken.

2.6 Weather Stations

Three portable environmental monitoring stations were set up at the experiment site to monitor local weather conditions. The stations simultaneously log several types of meteorological data. These are wind speed, wind direction, temperature, barometric pressure and relative humidity.

Two of the stations were developed by Earth and Atmospheric Science, Inc (Geneq Inc., Montreal, QC). One station was positioned 105 m upwind of the burn pan along the primary line of instruments, the second was placed approximately 75 m southeast of the test tank and the third was located 90 m downwind of the test tank along the primary line of instruments.

3.0 Results and Discussion

3.1 PAHs in Oil, Residue and Water

Table 3 shows the results of the PAH analysis of the oil and residue and Table 4 similar results for the PAHs in the water under the fire. It is apparent from the data that the distribution of the PAHs is different in the starting oil than in the residue and also in the water column. Table 3 shows that the total PAHs in the starting diesel fuel and the residues is about the same. The amount of phenathrenes and dibenzo thiophenes is somewhat increased whereas the naphthalenes are reduced by the combustion. The amount of larger PAHs, eg. benz(a)anthracene to benzo(ghi)perylene are increased from a low concentration to a measureable concentration by combustion. The relative concentrations of the alkylated PAHs are shown in Figure 2. This chart shows the typical trends for the alkylated PAHs after diesel combustion. The naphthalenes are reduced, phenanthrenes increased somewhat, the dibenzothiophenes increased significantly, fluorenes increased somewhat and the

Table 3 **Distribution of Alkylated PAHs and other EPA Priority PAHs in Diesel and Residue Samples**

Sample Type PAHs	Diesel fresh (µg/g oil)	Diesel Wth 8.34% (µg/g oil)	Diesel Wth 14.25% (µg/g oil)	Residue Boom 1 (µg/g oil)	Residue Boom 2 (µg/g oil)	Residue Boom 3 (µg/g oil)	Residue Boom 4 (µg/g oil)
Naphthalene							
C0-N	288	234	150	13	63	86	68
C1-N	1981	1994	1770	57	380	408	556
C2-N	4886	5392	5236	469	1534	1898	2492
C3-N	4669	4634	4689	1010	1933	2688	3431
C4-N	1995	2269	2271	732	1082	1415	1916
Sum	**13819**	**14524**	**14116**	**2281**	**4992**	**6494**	**8462**
Phenanthrene							
C0-P	338	369	392	285	289	405	447
C1-P	1193	1352	1408	1331	1218	1618	1858
C2-P	1209	1356	1427	1912	1721	2059	2200
C3-P	709	779	809	1489	1217	1360	1470
C4-P	252	257	275	683	510	492	561
Sum	**3701**	**4113**	**4311**	**5700**	**4954**	**5934**	**6536**
Dibenzothiophene							
C0-D	687	740	765	539	602	818	809
C1-D	1667	1945	1973	1963	1939	2602	2554
C2-D	2291	2539	2577	3536	3179	3883	3989
C3-D	1069	1117	1130	2219	1753	2017	2037
Sum	**5714**	**6341**	**6444**	**8256**	**7472**	**9321**	**9388**
Fluorene							
C0-F	221	230	244	80	125	168	187
C1-F	701	781	801	414	516	710	756
C2-F	1152	1348	1398	1186	1102	1539	1756
C3-F	944	1114	1153	1373	1148	1487	1630
Sum	**3018**	**3473**	**3596**	**3054**	**2891**	**3904**	**4330**
Chrysene							
C0-C	17	14	17	89	63	46	54
C1-C	24	16	18	110	80	49	59
C2-C	14	12	15	102	67	35	45
C3-C	6	4	6	48	32	15	14
Sum	**61**	**46**	**56**	**349**	**242**	**145**	**173**
TOTAL	**26313**	**28498**	**28523**	**19639**	**20551**	**25799**	**28890**
Other PAHs							
Biphenyl	285.4	227.4	283.9	15.1	100.9	91.7	92.3
Acenaphthalene	17.1	12.3	16.1	30.0	62.8	76.9	59.4
Acenaphthene	64.3	57.9	74.7	8.9	28.2	32.0	42.1
Anthracene	4.7	2.6	2.9	17.2	27.9	29.9	27.3
Fluoranthene	1.8	1.9	2.1	30.0	34.7	42.7	46.1
Pyrene	22.4	16.7	24.5	64.5	73.5	82.5	99.6
Benz(a)anthracene	2.4	2.3	2.5	27.4	17.7	19.8	21.6
Benzo(b)fluoranthene	0.4	0.3	0.3	16.0	9.5	14.3	16.7
Benzo(k)fluoranthene	0.1	0.0	0.0	19.8	10.6	15.4	17.4
Benzo(e)pyrene	0.7	0.7	0.7	16.6	10.2	8.4	10.4
Benzo(a)pyrene	0.2	0.1	0.1	29.8	15.5	16.2	18.0
Perylene	0.2	0.1	0.1	9.2	4.7	3.7	4.2
Indeno(1,2,3cd)pyrene	0.0	0.0	0.0	1.6	7.0	7.5	7.5
Dibenz(a,h)anthracene	0.0	0.0	0.0	1.8	0.7	0.5	1.6
Benzo(ghi)perylene	0.0	0.0	0.0	22.0	10.4	11.6	12.0
TOTAL	**400**	**322**	**408**	**310**	**414**	**453**	**476**

Table 4 **PAH analysis results of Water Samples**

PAHs	Water Blank (µg/Kg H_2O)	After Boom 1 (µg/Kg H_2O)	After Boom 2 (µg/Kg H_2O)	After Boom 3 (µg/Kg H_2O)	After Boom 4 (µg/Kg H_2O)
Naphthalene					
C0-N	0.0052	0.037	1.589	0.200	0.178
C1-N	0.016	0.075	15.2	1.6	2.2
C2-N	0.030	1.0	161.7	38.4	57.9
C3-N	0.076	29.9	340.7	132.2	180.1
C4-N	0.12	46.1	205.6	99.0	137.5
Sum	0.2	77	725	271	378
Phenanthrene					
C0-P	0.02	0.69	46.39	7.35	7.23
C1-P	0.04	23.2	201.6	87.1	79.8
C2-P	0.11	78.0	316.2	149.4	144.8
C3-P	0.12	64.9	192.9	113.4	113.8
C4-P	0.15	24.0	80.8	42.9	41.6
Sum	0.4	191	838	400	387
Dibenzothiophene					
C0-D	0.0244	1.5	103.5	26.0	16.4
C1-D	0.0510	47.7	368.0	171.8	125.2
C2-D	0.0723	166.1	621.8	357.1	287.9
C3-D	0.0852	104.1	331.9	194.9	162.8
Sum	0.2	319	1425	750	592
Fluorene					
C0-F	0.0022	0.27	21.89	4.11	4.57
C1-F	0.0213	7.2	95.0	32.0	34.7
C2-F	0.24	44.2	238.2	104.5	102.4
C3-F	0.59	57.6	220.8	121.7	118.0
Sum	0.85	109	576	262	260
Chrysene					
C0-C	0.0332	2.4	9.2	4.7	4.2
C1-C	0.0133	2.7	9.9	4.9	4.4
C2-C	0.0066	2.0	7.7	3.5	3.3
C3-C	0.0000	0.8	2.7	1.4	1.3
Sum	0.053	7.9	29.5	14.5	13.1
TOTAL	1.82	704	3593	1698	1630
Other PAHs					
Biphenyl	0.0021	0.031	0.351	0.147	0.077
Acenaphthalene	0.0000	0.021	7.463	1.326	0.391
Acenaphthene	0.0000	0.052	2.213	0.940	1.111
Anthracene	0.0000	0.14	4.31	1.26	0.91
Fluoranthene	0.0125	0.42	7.80	3.37	2.46
Pyrene	0.0146	1.57	14.36	7.01	5.67
Benz(a)anthracene	0.0021	0.61	0.33	1.32	1.48
Benzo(b)fluoranthene	0.0000	0.28	1.64	0.74	0.55
Benzo(k)fluoranthene	0.0000	0.36	2.54	0.98	0.58
Benzo(e)pyrene	0.0000	0.35	1.77	0.73	1.00
Benzo(a)pyrene	0.0000	0.40	2.32	0.94	0.73
Perylene	0.0000	0.13	0.67	0.26	0.24
Indeno(1,2,3cd)pyrene	0.0000	0.22	1.75	0.65	0.63
Dibenz(a,h)anthracene	0.0000	0.005	0.229	0.091	0.021
Benzo(ghi)perylene	0.0000	0.32	2.05	0.78	0.78
TOTAL	0.0312	4.93	49.79	20.55	16.62

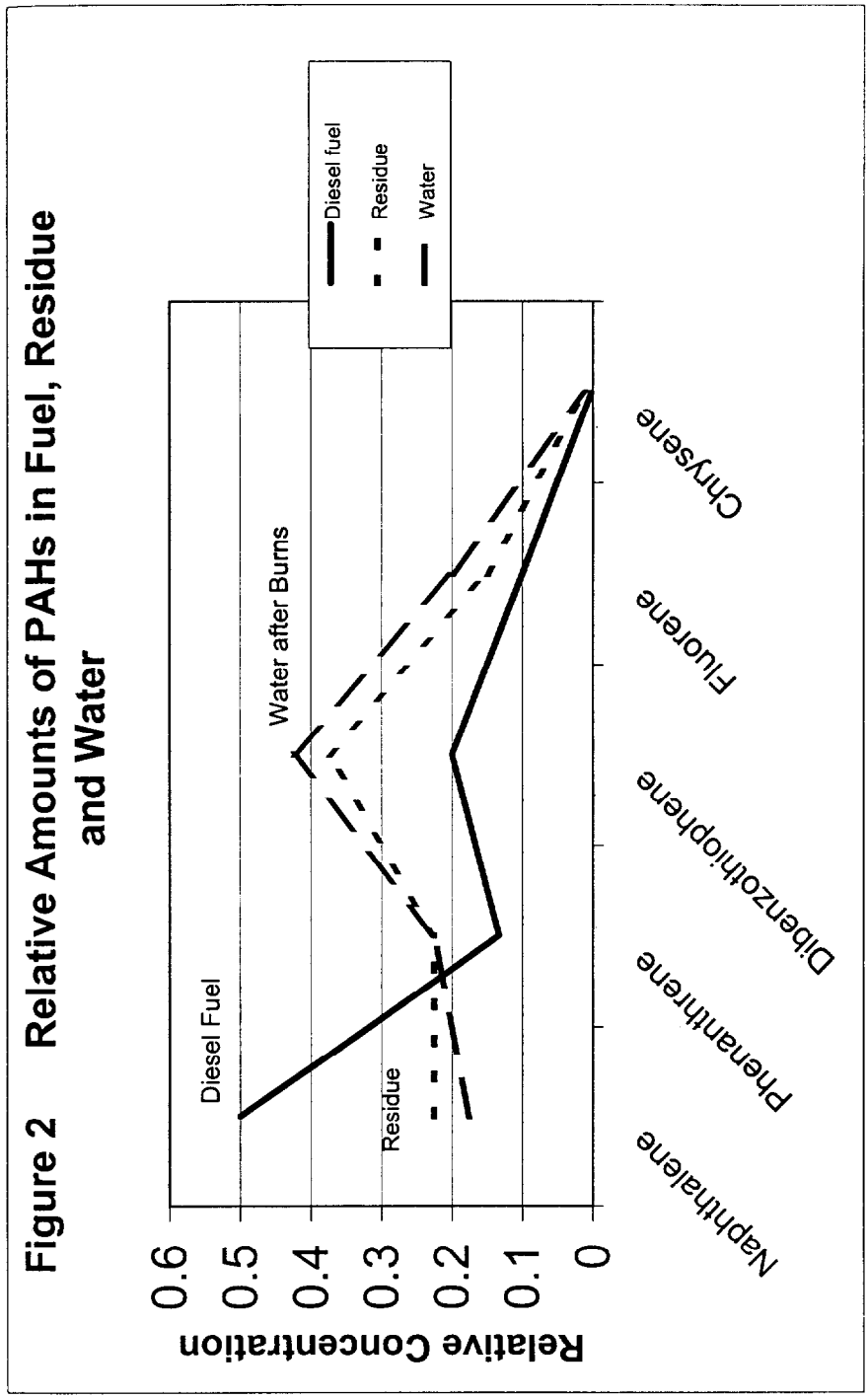
Figure 2 Relative Amounts of PAHs in Fuel, Residue and Water
Relative Concentration
0.6
0.5
0.4
0.3
0.2
0.1
0
Diesel Fuel
Water after Burns
Residue
Diesel fuel
Residue
Water
Naphthalene
Phenanthrene
Dibenzothiophene
Fluorene
Chrysene

chrysenes are about the same. The overall concentration of the alkylated PAHs are about the same in the starting diesel and the residue. This is consistent with findings on previous diesel burns where the PAH distributions have been studied in detail (Wang *et al.* 1998). This same trend has not been observed in crude oil fires, however sufficient data have not been available to perform extensive studies.

3.2 Gases and VOCs by Long-Path Infrared

The data from the long-path infrared instrument is summarized in Table 5. Only those compounds which showed several appearances over the background level are shown in Table 5. The values here are in ppm (actually ppm/m) which was derived by calculating the total concentration over the path length of 120 metres and then dividing that by 120. If the target compound passes through only a small cross-sectional area of the path, its specific concentration is much less than the average. Because of the long 120 m path length used here, the concentrations noted in Table 5, are felt to be very much under the maximum concentrations. For example if the cloud of gas was only 10 m (30 feet) in width, then the actual concentration would be 12 times the value noted in Table 5. Thus, the concentrations noted in Table 5 can be taken only as average concentrations.

The concentrations of carbon dioxide measured using long-path infrared corresponds very well to that measured by conventional instruments as reported in a previous paper (Fingas *et al.*, 1998). The three greatest peaks of carbon dioxide were found in conventional instruments to be for boom 3, burn 1; and boom 4, burn 1 and 2. These correspond exactly to the largest peaks noted in the long-path infrared.

The carbon monoxide levels are at threshold levels and appear to correlate somewhat with the carbon dioxide levels, indicating that drift conditions are similar for the two gases. The VOCs, ethyl benzene, iso-octane, n-octane and benzene, are also at threshold levels. The amounts of these are typically highest in the pre-burn phase when the diesel fuel is being loaded. This confirms the earlier findings that the evaporation of these components is more significant than their emission during the actual fire.

3.3 Carbonyls

Table 6 shows the concentrations of the carbonyls measured at one downwind station less the concentrations measured at the 'upwind' station. On occasion, winds did not necessarily blow over the downwind station, and may have impacted the upwind station, at least for some time. The negative values shown in Table 6 may be the result of this wind reversal, but may also be a result of the variable and high background of carbonyls such as formaldehyde and acetone. The levels of these compounds is influenced strongly by the high amount of industrial activity in the Mobile area.

Table 6 shows that significant amounts of formaldehyde, acetaldehyde acetone, proprionaldehyde and MEK (methyl ethyl ketone) result from diesel fires, although the amounts are variable and measurement depends on local meteorological conditions.

3.4 Carbon Dioxide from Summa Canisters

Table 7 summarizes the carbon dioxide levels as measured in the Summa canisters. The highest levels above background level again correspond to the other

Table 5 **Gases and VOCs Detected by Long-Path Infrared**

	Gas concentration in ppm/m above background levels					
Burn Identification	Carbon Dioxide	Carbon Monoxide	Ethyl Benzene	Iso-Octane	n-Octane	Benzene
Pre-Background	0<1.88<15.44	0<0.01<0.15	0<0<0	0<0<0	0<0<0	0<0.16<0.26
Background	0<2.73<19.14	0<0<0	0<0<0	0<0<0	0<0<0	0<0<0
Burn - Boom 1 Burn 1	0<3.71<11.26	0<0<0	0<0<0	0<0<0.01	0<0<0.02	0<0<0
Post-burn - Boom 1 Burn 1	0<0.85<5.94	0<0<0	0<0<0	0<0<0	0<0<0	0<0<0
Pre-Burn Boom 2 Burn 1	0<0<0	0<0<0	0<0<0.03	0<0<0.01	0<0.01<0.05	0<0<0
Burn Boom 2 Burn 1	0<0<0	0<0<0	0<0<0	0<0<0	0<0.01<0.06	0<0<0
Pre-burn Boom 2 Burn 2	0<0<0	0<0<0	0<0<0	0<0<0	0<0.01<0.03	0<0<0
Burn Boom 2 Burn 2	0<0<0	0<0<0	0<0<0	0<0<0	0<0<0	0<0<0
Post-burn Boom 2 Burn 2	0<0<0	0<0.03<0.12	0<0<0	0<0<0	0<0.01<0.06	0<0<0
Pre-burn Boom 2 Burn 3	0<0<0	0<0<0	0<0<0	0<0<0	0<0.03<0.06	0<0<0
Burn Boom 2 Burn 3	0<0<0	0<0.03<0.16	0<0<0	0<0<0	0<0<0	0<0<0
Post-burn Boom 2 Burn 3	0<0<0	0<0.06<0.11	0<0<0	0<0<0	0<0<0	0<0<0
Pre-burn - Boom 3 Burn 1	0<2.49<10.37	0<0<0.02	0<0<0	0<0<0	0<0<0	0<0.08<0.26
Burn - Boom 3 Burn 1	0<2.51<12.47	0<0.01<0.09	0<0<0	0<0<0	0<0<0	0<0<0
Post-burn - Boom 3 Burn 1	0<0.6<8.39	0<0<0	0<0<0	0<0<0	0<0<0	0<0<0
Pre-burn - Boom 4 Burn 1	0<0<0	0.01<0.09<0.23	0<0<0.03	0<0<0.01	0<0.01<0.03	0<0.08<0.31
Burn - Boom 4 Burn 1	0<2.5<19.36	0<0.1<0.18	0<0<0	0<0<0	0<0.01<0.07	0<0<0
Post-burn - Boom 4 Burn 1	0<0<0	0<0<0	0<0<0	0<0<0	0.07<0.08<0.1	0<0<0
Pre-burn - Boom 4 Burn 2	1.45<3.4<5.34	0<0.01<0.02	0<0<0	0<0<0	0.01<0.02<0.03	0<0<0
Burn - Boom 4 Burn 2	0<3.69<9.04	0<0.01<0.06	0<0<0	0<0<0	0<0<0.04	0<0<0
Post-burn - Boom 4 Burn 2	0<2.74<8.85	0<0<0.02	0<0<0	0<0<0	0<0.03<0.06	0<0<0
Pre-burn - Boom 4 Burn 3	0<0<0	0<0.01<0.04	0<0<0	0<0<0	0<0<0	0<0<0
Burn - Boom 4 Burn 3	0<0<0	0<0.02<0.14	0<0<0	0<0<0	0<0<0.1	0<0<0
Post-burn - Boom 4 Burn 3	0<0<0	0<0.07<0.12	0<0<0	0<0<0	0<0.01<0.07	0<0<0

Results are reported as MIN<AVE<MAX
ppm = parts-per-million.

Table 6 **Carbonyl Measurements**

(concentrations in µg/m^3 above background measurement)

Burn Identification	Boom 2 Burn 1	Boom 2 Burn 2	Boom 2 Burn 3	Boom 3 Burn 1	Boom 3a Burn 1
Sample Position	DW2B	DW2B	DW2B	DW2B	DW2B
Compounds	189°, 30m	189°, 30m	189°, 30m	189°, 30m	189°, 30m
Formaldehyde	0.965	-0.512	0.314	5.145	7.523
Acetaldehyde	1.700	-0.702	-0.342	5.698	10.657
Acrolein	0.000	0.000	0.000	0.000	0.405
Acetone	-0.891	-0.175	-0.213	8.814	12.038
Propionaldehyde	0.535	0.237	0.956	0.665	1.652
Crotonaldehyde	0.000	-0.678	0.000	0.000	0.000
MEK	0.677	0.491	-0.687	3.684	4.510
Benzaldehyde	0.000	0.000	0.000	0.000	0.000
Isovaleraldehyde	0.000	0.000	0.000	0.000	0.000
2-Pentanone	0.000	0.000	0.000	0.000	0.000
Valeraldehyde	0.000	0.000	0.000	0.000	0.702
o-Tolualdehyde	0.000	0.000	0.000	0.000	0.000
m-Tolualdehyde	0.000	0.000	0.000	2.829	2.202
p-Tolualdehyde	0.000	0.000	0.000	0.000	0.000
MIBK	0.000	0.000	0.000	0.000	0.000
Hexanal	0.000	0.000	0.000	0.000	0.000
2,5-Dimethylbenzaldehyde	0.000	0.000	0.000	0.000	0.000

Burn Identification	Boom 4 Burn 1	Boom 4 Burn 2	Boom 4 Burn 3	Boom 5 Burn 1	Blank\Ambient
Sample Position	DW2B	DW2B	DW2B	DW2B	DW2B
Compounds	189°, 30m	189°, 30m	189°, 30m	189°, 30m	189°, 30m
Formaldehyde	0.110	0.049	-0.530	-0.158	0.064
Acetaldehyde	0.660	-2.109	-1.536	-1.673	0.056
Acrolein	0.547	0.000	0.000	0.000	0.000
Acetone	-0.708	-0.343	0.603	-0.339	0.251
Propionaldehyde	-0.169	-0.154	0.248	-0.288	0.000
Crotonaldehyde	0.000	0.000	-1.074	0.000	0.000
MEK	0.042	0.120	0.759	0.084	0.108
Benzaldehyde	-2.350	-1.902	-2.404	0.000	0.000
Isovaleraldehyde	0.000	0.000	0.000	0.000	0.000
2-Pentanone	0.000	0.000	0.000	0.000	0.000
Valeraldehyde	0.000	-1.182	-1.394	0.000	0.000
o-Tolualdehyde	0.000	0.000	0.000	0.000	0.000
m-Tolualdehyde	0.000	0.000	0.000	0.000	0.000
p-Tolualdehyde	0.000	0.000	0.000	0.000	0.000
MIBK	0.000	0.000	0.000	0.000	0.000
Hexanal	0.000	0.000	0.000	0.000	0.000
2,5-Dimethylbenzaldehyde	0.000	0.000	0.000	0.000	0.000

**negative values indicate background levels higher, or carbonyl plume blowing over background station*

Table 7

Carbon Dioxide Measured in SUMMA Canisters

(values in ppm)

location	DW1A 170°, 30m	DW1B 186°, 15m	DW2B 189°, 30m	DW3B 191°, 45m	DW1C 214°, 30m	UW1B 25°, 72m
Boom 1 Burn 1 (Sept 25, 97)	347	328	353	290 297	334	331
Boom 2 Burn 1 (Sept 26, 97)	325	327	333	322	310	318
Boom 2 Burn 2 (Sept 26, 97)	329	324	319		346	326
Boom 2 Burn 3 (Sept 26, 97)	320	339	315		311	317
Boom 3 Burn 1 (Sept 29, 97)	355	314	296		318	328
Boom 3a Burn 1 (Sept 30, 97)	341	334	343		341	340
Boom 4 Burn 1 (Oct 1, 97)	350	359 367	356		357	351
Boom 4 Burn 2 (Oct 1, 97)	345	331	324		331	341
Boom 4 Burn 3 (Oct 1, 97)	318	320	324		323	308 294
Boom 5 Burn 1 (Oct 2, 97)	312	318	320		320	318

location	S1A	S2A	S3A	S1C	S2C	S3C	UW1B
Boom 3 Burn 1 (Sept 29, 97)	316	312	323	323	325	342	340
Boom 3a Burn 1 + Boom 4	335	347	332	324	352	335	353
Boom 5 Burn 1 (Oct 2, 97)	308	311	332	324 319	335	308	

Values above the upwind station

(values in ppm above upwind station)

location	DW1A 170°, 30m	DW1B 186°, 15m	DW2B 189°, 30m	DW3B 191°, 45m	DW1C 214°, 30m
Boom 1 Burn 1 (Sept 25, 97)	16	0	22	0 0	3
Boom 2 Burn 1 (Sept 26, 97)	7	8	15	4	0
Boom 2 Burn 2 (Sept 26, 97)	3	0	0	-	20
Boom 2 Burn 3 (Sept 26, 97)	2	21	0	-	0
Boom 3 Burn 1 (Sept 29, 97)	27	0	0	-	0
Boom 3a Burn 1 (Sept 30, 97)	1	0	2	-	1
Boom 4 Burn 1 (Oct 1, 97)	0	8	5	-	6
Boom 4 Burn 2 (Oct 1, 97)	5	0	0	-	0
Boom 4 Burn 3 (Oct 1, 97)	10	12	16	-	15
Boom 5 Burn 1 (Oct 2, 97)	0	0	2	-	2

location	S1A	S2A	S3A	S1C	S2C	S3C
Boom 3 Burn 1 (Sept 29, 97)	0	0	0	0	0	2
Boom 3a Burn 1 + Boom 4	0	0	0	0	0	0
Boom 5 Burn 1 (Oct 2, 97)	0	3	24	16 1	27	0

types of carbon dioxide measurements made, those from the long-path infrared and those from the conventional instrument array. The measurements of carbon dioxide from Summa canisters show significant variance, however add confirmation to the other types of measurement.

3.4 VOCs from Summa Canisters

A total of 146 analytes were measured in the Summa canisters by gas chromatography. The sum of the hydrocarbons measured is given in Table 8. It can be seen that the total amount of VOCs is sometimes less than the upwind value, however, it must be remembered that the upwind station may have received compounds during the fueling stage of the test burns and that these values do not necessarily represent the background values. The levels are consistent with those found previously at small diesel fires. The analytes detected at any fire are listed in Table 9. These are typical hydrocarbons contained in crude and petroleum products. Table A in the appendix lists the specific results of the VOCs found during the 1997 burn test series. The compounds are listed in decreasing order of quantity found during the burn. The order in terms of the largest concentration is: hexane, toluene, dodecane, propane, butane and so on. This is as expected from previous burn work.

4.0 Conclusions

Diesel fuel contains significant quantities of PAHs. These are largely destroyed in combustion. The PAH concentrations in the smoke, both in the plume and the particulate precipitation at ground level are less than the starting oil. This also includes the concentration of most multi-ringed PAHs that are often created in other combustion processes such as low-temperature incinerators and diesel engines. Burns of diesel fuel show an increase in the concentration of some multi-ringed PAHs, but still a net destruction of PAHs is noted. The naphthalenes are reduced, phenanthrenes increased somewhat, the dibenzothiophenes increased significantly, fluorenes increased somewhat and the chrysenes are about the same. The overall concentration of the alkylated PAHs are about the same in the starting diesel and the residue. The amount of larger PAHs, eg. benz(a)anthracene to benzo(ghi)perylene are increased from a low concentration to a measureable concentration by combustion. This phenomenon has been measured for diesel fires, but not for crude oil fires.

The results from the long-path IR show that this measurement technique has potential for burn measurement and the results do correlate with conventional measurement techniques. Combustion gases measured with the technique, such as carbon dioxide and carbon monoxide are significantly under any concern level. The hydrocarbons measured show higher concentrations before the burn than during burning, indicating that these compounds are largely released by evaporation and destroyed by the fire when started.

Carbonyls such as aldehydes and ketones are created by oil fires, but do not exceed health exposure limits even very near fires. Significant amounts of formaldehyde, acetaldehyde acetone, proprionaldehyde and MEK (methyl ethyl ketone) result from diesel fires, although the amounts are variable and measurement depends on local meteorological conditions.

Many volatile organic compounds are emitted by fires, but in lesser quantity than when the oil is not burning. VOCs are not a concern, but can rise to close to concern levels very near a fire (<100 m). The VOC compounds released in greatest

Table 8 **Total VOCs as Measured in SUMMA Canisters**

(values in µg/m³)

	DW1A 170°, 30m	DW1B 186°, 15m	DW2B 189°, 30m	DW3B 191°, 45m	DW1C 214°, 30m	UW1B 25°, 72m
Boom 1 Burn 1 (Sept 25, 97)	43	50	50	37	54	37
Boom 2 Burn 1 (Sept 26, 97)	36	132	561	18	32	22
Boom 2 Burn 2 (Sept 26, 97)	38	61	31		58	14
Boom 2 Burn 3 (Sept 26, 97)	28	129	67		48	18
Boom 3 Burn 1 (Sept 29, 97)	96	86	97		91	106
Boom 3a Burn 1 (Sept 30, 97)	144	120	135		127	142
Boom 4 Burn 1 (Oct 1, 97)	117	143	116		197	224
Boom 4 Burn 2 (Oct 1, 97)	47	440	417		80	47
Boom 4 Burn 3 (Oct 1, 97)	32	254	65		250	18
Boom 5 Burn 1 (Oct 2, 97)	17	112	21		29	5

	S1A 53°, 45m	S2A 110°, 45m	S3A 142°, 42m	S1C 341°, 35m	S2C 286°, 45m	S3C 238°, 25m	UW1B 25°, 72m
Boom 3 Burn 1 (Sept 29, 97)	116	373	77	192	222	208	191
Boom 5 Burn 1 (Oct 2, 97)	11	11	8	56	25	23	
Boom 3a Burn 1 + Boom 4 Burn 1, 2, & 3	107	107	92	111	91	114	118

Table 9 **Volatile Organic Compounds Found from Evaporating or Burning Oils**

Propene
Propane
Isobutane (2-Methylpropane)
1-Butene/2-Methylpropene
1,3-Butadiene
Butane
t-2-Butene
2,2-Dimethylpropane
1-Butyne
c-2-Butene
2-Methylbutane
1-Pentene
2-Methyl-1-Butene
Pentane
Isoprene (2-Methyl-1,3-Butadiene)
2-Methyl-2-Butene
2,2-Dimethylbutane
Cyclopentene
4-Methyl-1-Pentene
3-Methyl-1-Pentene
Cyclopentane
2,3-Dimethylbutane
t-4-Methyl-2-Pentene
2-Methylpentane
c-4-Methyl-2-Pentene
3-Methylpentane
1-Hexene/2-Methyl-1-Pentene
t-2-Hexene
2-Ethyl-1-Butene
t-3-Methyl-2-Pentene
c-2-Hexene
c-3-Methyl-2-Pentene
2,2-Dimethylpentane
Methylcyclopentane
2,4-Dimethylpentane
2,2,3-Trimethylbutane
1-Methylcyclopentene
Benzene
Cyclohexane
2-Methylhexane
2,3-Dimethylpentane
Cyclohexene
3-Methylhexane
2,2,4-Trimethylpentane
t-3-Heptene
Heptane
t-2-Heptene
c-2-Heptene
2,2-Dimethylhexane
Methylcyclohexane
2,5-Dimethylhexane
2,4-Dimethylhexane
2,3,4-Trimethylpentane
Toluene
2-Methylheptane
4-Methylheptane
1-Methylcyclohexene
3-Methylheptane
c-1,3-Dimethylcyclohexane
t-1,4-Dimethylcyclohexane
2,2,5-Trimethylhexane
Octane
t-1,2-Dimethylcyclohexane
t-2-Octene
c-1,4/t-1,3-Dimethylcyclohexane
c-2-Octene
c-1,2-Dimethylcyclohexane
Ethylbenzene
m/p-Xylene
o-Xylene
Nonane
iso-Propylbenzene
3,6-Dimethyloctane
n-Propylbenzene
3-Ethyltoluene
4-Ethyltoluene
1,3,5-Trimethylbenzene
2-Ethyltoluene
tert-Butylbenzene
1,2,4-Trimethylbenzene
Decane
iso-Butylbenzene
sec-Butylbenzene
1,2,3-Trimethylbenzene
p-Cymene
Indane
1,3-Diethylbenzene
1,4-Diethylbenzene
n-Butylbenzene
1,2-Diethylbenzene
Undecane
Naphthalene
Dodecane
Hexylbenzene

amounts are: hexane, toluene, dodecane, propane, butane, etc.

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TableA1 **VOCs Measured in Summa Canisters**

Burn Identification		Bm1Br1	Bm1Br1	Bm1Br1	Bm1Br1	Bm1Br1	Bm1Br1	Bm2Br1	Bm2Br1
Location		DW1A	DW1B	DW2B	DW3B	DW1C	UW1B	DW1A	DW1B
All values in µg/m³ Position		170°, 30m	186°, 15m	189°, 30m	191°, 45m	214°, 30m	25°, 72m	170°, 30m	186°, 15m
TOTAL VOC (µg/m³)		43	50	50	37	54	37	36	132
Propene	93.08	0.43	0.53	0.49	0.50	0.73	1.04	1.51	2.86
Propane	406.63	5.61	6.61	6.45	4.87	8.07	5.22	2.86	3.31
Isobutane (2-Methylpropane)	152.29	1.59	1.52	1.64	1.48	1.68	1.61	0.48	0.53
1-Butene/2-Methylpropene	79.71	0.74	0.66	0.62	0.74	0.92	0.92	1.24	1.54
1,3-Butadiene	12.76	ND	< DL	ND	ND	0.11	ND	0.34	0.73
Butane	365.24	3.06	3.19	3.17	2.73	3.22	2.88	1.22	1.26
Isoprene (2-Methyl-1,3-Butadiene)	75.69	0.88	0.93	0.96	0.80	1.02	1.64	0.64	0.80
t-2-Pentene	12.85	ND	ND	ND	ND	ND	ND	0.07	NDR
2-Methyl-2-Butene	20.84	ND	0.11	ND	0.08	0.09	0.07	0.09	0.11
2,2-Dimethylbutane	26.71	0.15	0.21	0.20	0.16	0.21	< DL	0.13	0.15
Cyclopentane	21.60	0.15	0.14	0.16	0.12	0.16	0.10	ND	0.10
2,3-Dimethylbutane	42.63	0.19	0.19	0.26	0.17	0.26	0.20	0.11	0.11
2-Methylpentane	129.89	NDR	NDR	NDR	NDR	NDR	NDR	NDR	NDR
3-Methylpentane	119.78	0.82	0.63	0.87	0.63	0.76	0.57	0.29	0.35
1-Hexene/2-Methyl-1-Pentene	30.05	0.26	0.22	0.30	0.26	0.28	0.31	0.44	0.46
Hexane	903.80	7.77	2.89	7.73	4.21	5.36	4.58	1.95	1.44
Methylcyclopentane	133.23	NDR	0.56	1.07	0.62	0.85	NDR	0.36	0.39
2,4-Dimethylpentane	28.01	ND	0.14	ND	ND	0.17	0.17	ND	ND
Benzene	243.88	1.18	1.57	1.42	1.16	1.72	0.98	2.21	6.09
Cyclohexane	23.88	0.16	0.29	0.31	0.22	0.43	NDR	0.13	0.29
2-Methylhexane	52.30	0.30	0.48	0.46	0.32	0.49	NDR	0.22	0.42
2,3-Dimethylpentane	30.52	NDR	NDR	NDR	NDR	NDR	0.17	< DL	NDR
3-Methylhexane	21.49	NDR	NDR	NDR	NDR	NDR	0.36	NDR	NDR
2,2,4-Trimethylpentane	92.37	0.28	0.25	0.27	0.23	0.38	0.31	0.22	NDR
Heptane	73.54	0.60	1.03	0.89	0.78	1.13	0.45	0.59	1.12
Methylcyclohexane	49.43	0.27	0.66	0.58	0.45	0.74	0.13	0.30	0.98
2,5-Dimethylhexane	16.39	NDR	0.14	NDR	NDR	0.14	NDR	0.07	0.16
2,4-Dimethylhexane	19.17	NDR	0.28	NDR	NDR	0.17	NDR	NDR	0.15
2,3,4-Trimethylpentane	34.28	ND	ND	ND	ND	0.16	NDR	ND	ND
Toluene	673.85	3.69	4.49	4.55	3.05	4.43	3.05	2.60	4.53
2-Methylheptane	43.03	0.26	0.70	0.49	0.37	0.53	0.48	0.24	0.80
4-Methylheptane	24.63	0.25	NDR	0.26	NDR	0.25	NDR	0.13	0.22
3-Methylheptane	30.15	0.19	0.36	0.32	0.24	0.37	NDR	0.22	0.47
2,2,5-Trimethylhexane	22.89	0.05	0.05	ND	0.04	0.11	ND	NDR	0.06
1-Octene	15.78	0.19	0.31	< DL	0.28	0.26	0.39	0.39	0.39
Octane	84.48	0.50	1.15	0.96	0.79	1.15	0.41	0.61	2.02
t-1,2-Dimethylcyclohexane	14.96	0.08	0.18	0.15	0.09	0.17	ND	0.09	0.43
Ethylbenzene	93.59	0.59	0.82	0.67	0.55	0.69	0.59	0.72	1.17
m,p-Xylene	346.06	1.85	2.77	2.19	1.82	2.37	1.67	2.20	4.67
Styrene	13.56	NDR	0.15	0.11	0.13	0.07	0.21	0.18	0.67
o-Xylene	126.02	0.56	0.92	0.73	0.62	0.89	0.50	0.72	2.04
Nonane	119.90	0.41	1.16	0.79	0.60	1.11	0.41	0.69	3.55
iso-Propylbenzene	11.22	0.05	0.07	0.07	0.04	0.07	0.04	0.06	0.17
n-Propylbenzene	27.75	0.08	0.13	0.10	0.11	0.14	0.08	0.11	0.38
3-Ethyltoluene	82.89	0.18	0.31	0.25	0.20	0.36	0.13	0.27	1.17
4-Ethyltoluene	40.21	0.10	0.17	0.13	0.10	0.18	< DL	0.14	0.57
1,3,5-Trimethylbenzene	52.27	0.10	0.20	0.15	0.11	0.21	0.06	0.20	1.07
2-Ethyltoluene	37.21	0.10	0.17	0.13	0.10	0.19	0.07	0.15	0.70
1,2,4-Trimethylbenzene	157.94	0.30	0.59	0.45	0.33	0.63	0.21	0.59	3.19
Decane	194.17	0.45	0.95	0.66	0.46	0.89	0.27	0.91	5.96
1,2,3-Trimethylbenzene	42.87	0.10	0.19	0.13	0.11	0.20	0.06	0.19	1.10
p-Cymene (1-Methyl-4-iso-propylbenzene)	10.03	0.15	0.10	0.11	0.10	0.10	0.10	0.07	0.20
1,3-Diethylbenzene	10.01	ND	0.06	ND	< DL	0.05	ND	0.06	0.23
1,4-Diethylbenzene	35.34	0.13	0.16	ND	0.13	0.15	NDR	0.19	0.98
n-Butylbenzene	11.79	0.06	0.09	0.05	0.07	0.06	0.08	0.06	0.26
Undecane	341.69	1.04	1.70	1.20	0.67	1.05	0.27	1.68	15.65
Naphthalene	64.66	0.42	0.24	0.21	0.19	0.13	0.66	0.48	3.87
Dodecane	597.33	1.77	2.92	1.82	0.79	1.57	0.26	2.93	45.9
Hexylbenzene	13.07	0.11	ND	0.08	ND	0.08	0.10	0.11	1.25

< DL = Lower then Detectable Limits
ND = Not detected
NDR = Not detected due to "out of spec" ion ratio(s)
XS = Concentration exceeded detector range
Propane values corrected for Blank

TableA2 **VOCs Measured in Summa Canisters**

Burn identification	Bm2Br1	Bm2Br1	Bm2Br1	Bm2Br1	Bm2Br2	Bm2Br2	Bm2Br2	Bm2Br2	Bm2Br2
Location	DW2B	DW3B	DW1C	UW1B	DW1A	DW1B	DW2B	DW1C	UW1B
All values in µg/m³ Position	189°, 30m	191°, 45m	214°, 30m	25°, 72m	170°, 30m	186°, 15m	189°, 30m	214°, 30m	25°, 72m
TOTAL VOC (µg/m³)	561	18	32	22	38	61	31	58	14
Propene	2.43	0.32	0.27	0.35	1.06	1.32	0.86	0.94	0.18
Propane	3.41	4.32	3.12	2.57	2.67	2.24	2.29	2.53	2.28
Isobutane (2-Methylpropane)	5.31	0.42	0.53	0.45	0.61	0.43	0.39	0.40	0.38
1-Butene/2-Methylpropene	1.71	0.42	0.35	0.56	1.26	1.68	0.84	0.83	0.36
1,3-Butadiene	0.54	0.10	ND	< DL	0.20	0.28	0.16	0.18	ND
Butane	31.7	0.96	1.51	1.19	2.05	1.01	0.87	0.97	0.89
Isoprene (2-Methyl-1,3-Butadiene)	0.80	0.24	0.47	1.54	0.48	0.60	0.47	0.59	0.94
t-2-Pentene	3.31	ND	ND	ND	0.14	NDR	ND	NDR	ND
2-Methyl-2-Butene	5.07	ND	ND	0.07	0.22	0.12	0.09	0.07	ND
2,2-Dimethylbutane	3.56	< DL	< DL	0.13	0.27	NDR	NDR	NDR	< DL
Cyclopentane	3.38	ND	0.08	ND	0.14	ND	ND	ND	0.05
2,3-Dimethylbutane	5.17	0.08	0.12	0.10	0.29	0.10	0.10	0.12	0.08
2-Methylpentane	16.5	NDR	0.42	NDR	NDR	NDR	NDR	NDR	NDR
3-Methylpentane	10.9	NDR	0.31	NDR	0.84	NDR	NDR	NDR	0.25
1-Hexene/2-Methyl-1-Pentene	1.59	< DL	ND	0.25	0.40	0.32	0.23	0.25	< DL
Hexane	17.1	0.52	0.81	1.34	5.77	2.40	4.31	3.59	2.17
Methylcyclopentane	5.13	0.13	NDR	0.22	0.82	0.38	0.57	0.58	NDR
2,4-Dimethylpentane	3.35	ND	0.10	ND	0.16	ND	0.11	ND	ND
Benzene	19.5	0.68	1.43	0.83	1.46	2.63	1.13	2.44	0.44
Cyclohexane	0.92	0.12	0.27	NDR	NDR	0.15	0.10	0.25	NDR
2-Methylhexane	4.05	0.20	0.33	0.14	0.25	0.27	NDR	0.38	NDR
2,3-Dimethylpentane	4.00	NDR	0.13	NDR	0.18	NDR	NDR	NDR	ND
3-Methylhexane	4.66	NDR	NDR	NDR	NDR	NDR	NDR	NDR	NDR
2,2,4-Trimethylpentane	6.23	0.15	0.23	0.18	0.40	0.26	0.23	0.28	0.12
Heptane	3.91	0.54	1.07	0.32	0.44	0.57	0.34	0.90	0.27
Methylcyclohexane	1.21	0.32	0.71	0.06	0.14	0.48	0.20	0.72	< DL
2,5-Dimethylhexane	1.09	ND	0.10	ND	0.10	NDR	NDR	NDR	ND
2,4-Dimethylhexane	1.31	ND	0.16	ND	< DL	NDR	NDR	NDR	ND
2,3,4-Trimethylpentane	2.08	ND	ND	ND	0.16	ND	ND	0.16	ND
Toluene	105	1.37	2.14	2.26	3.81	3.00	1.86	3.10	1.02
2-Methylheptane	1.53	0.20	0.61	ND	0.13	0.46	ND	0.57	ND
4-Methylheptane	0.63	0.05	0.12	ND	0.18	0.20	ND	0.22	0.11
3-Methylheptane	1.47	0.15	0.33	0.11	0.13	0.22	ND	0.31	ND
2,2,5-Trimethylhexane	0.99	ND	ND	ND	0.10	0.08	0.07	0.10	ND
1-Octene	ND	ND	ND	0.40	0.17	0.27	0.17	0.18	0.22
Octane	1.98	0.54	1.24	0.32	0.36	0.88	0.50	1.29	0.30
t-1,2-Dimethylcyclohexane	0.31	0.11	0.19	ND	ND	0.20	0.17	0.21	ND
Ethylbenzene	9.76	0.30	0.51	0.69	0.45	0.66	0.30	0.60	0.14
m,p-Xylene	42.6	0.95	1.67	1.93	1.60	2.94	1.14	2.74	0.39
Styrene	0.42	< DL	0.12	0.11	0.08	0.20	0.11	0.14	0.06
o-Xylene	11.2	0.36	0.63	0.51	0.54	1.32	0.51	1.27	0.14
Nonane	1.78	0.47	1.13	0.26	0.29	1.82	0.69	1.78	0.27
iso-Propylbenzene	0.56	0.05	0.07	0.04	0.05	0.10	0.04	0.10	< DL
n-Propylbenzene	2.38	0.08	0.11	0.06	0.12	0.24	0.10	0.23	< DL
3-Ethyltoluene	7.20	0.13	0.24	0.14	0.35	0.73	0.29	0.63	0.07
4-Ethyltoluene	3.85	< DL	0.13	< DL	0.19	0.35	0.15	0.31	< DL
1,3,5-Trimethylbenzene	3.74	0.10	0.22	0.07	0.18	0.62	0.22	0.55	0.04
2-Ethyltoluene	2.25	0.08	0.14	0.07	0.15	0.42	0.16	0.36	< DL
1,2,4-Trimethylbenzene	12.50	0.29	0.59	0.22	0.58	1.83	0.63	1.58	0.11
Decane	2.82	0.38	0.98	0.18	0.34	2.82	0.92	2.60	0.22
1,2,3-Trimethylbenzene	2.19	0.10	0.19	0.06	0.13	0.61	0.19	0.54	< DL
p-Cymene (1-Methyl-4-iso-propylbenzene)	0.19	0.06	0.05	ND	ND	0.12	ND	0.11	ND
1,3-Diethylbenzene	0.45	ND	< DL	ND	0.05	0.12	0.06	0.11	ND
1,4-Diethylbenzene	1.61	0.12	0.18	0.11	0.13	0.48	0.18	0.45	0.06
n-Butylbenzene	0.43	0.04	0.07	0.05	0.04	0.14	0.06	0.14	0.05
Undecane	5.43	0.41	1.61	0.15	0.62	6.08	2.00	5.64	0.23
Naphthalene	2.24	0.13	0.40	0.17	0.14	1.26	0.37	1.19	0.18
Dodecane	12.6	0.57	3.07	0.32	0.84	13.8	4.48	12.4	0.36
Hexylbenzene	0.40	0.07	0.14	ND	ND	0.47	NDR	0.32	NDR

< DL = Lower then Detectable Limits
ND = Not detected
NDR = Not detected due to "out of spec" Ion ratio(s)
XS = Concentration exceeded detector range
Propane values corrected for Blank

TableA3 **VOCs Measured in Summa Canisters**

Burn Identification	Bm2Br3	Bm2Br3	Bm2Br3	Bm2Br3	Bm2Br3	Bm3Br1	Bm3Br1	Bm3Br1	Bm3Br1
Location	DW1A	DW1B	DW2B	DW1C	UW1B	DW1A	DW1B	DW2B	DW1C
All values in µg/m³ Position	170°, 30m	186°, 15m	189°, 30m	214°, 30m	25°, 72m	170°, 30m	186°, 15m	189°, 30m	214°, 30m
TOTAL VOC (µg/m³)	28	129	67	48	18	96	86	97	91
Propene	0.59	1.01	0.99	0.61	0.20	1.58	1.36	1.30	1.30
Propane	2.36	2.67	2.39	3.92	2.65	7.80	7.30	7.86	7.69
Isobutane (2-Methylpropane)	0.40	0.51	0.45	1.25	0.51	4.16	3.92	3.88	4.12
1-Butene/2-Methylpropene	0.60	0.77	0.79	0.66	0.34	1.29	1.00	1.05	0.86
1,3-Butadiene	0.11	0.22	0.23	0.12	ND	0.25	0.20	0.15	0.16
Butane	0.97	1.19	1.02	1.80	1.19	8.25	7.80	8.03	7.98
Isoprene (2-Methyl-1,3-Butadiene)	1.03	1.03	1.03	0.90	1.16	2.22	2.15	2.22	2.13
t-2-Pentene	ND	0.07	ND	< DL	ND	0.15	0.16	0.14	0.16
2-Methyl-2-Butene	ND	0.11	0.08	0.06	ND	0.16	0.18	0.21	0.20
2,2-Dimethylbutane	< DL	< DL	0.13	0.15	< DL	0.62	0.57	0.52	0.57
Cyclopentane	0.06	0.08	0.07	0.16	0.06	0.43	0.37	0.40	0.39
2,3-Dimethylbutane	0.09	0.15	0.10	0.23	0.13	0.84	0.71	0.75	0.76
2-Methylpentane	NDR	NDR	NDR	NDR	NDR	2.88	NDR	2.25	2.30
3-Methylpentane	NDR	0.42	0.35	0.68	0.37	1.66	1.49	1.59	1.53
1-Hexene/2-Methyl-1-Pentene	ND	< DL	0.26	0.22	< DL	0.35	0.29	0.43	0.25
Hexane	1.35	2.47	2.69	5.10	2.99	2.09	1.79	2.34	1.90
Methylcyclopentane	0.26	0.47	0.43	0.85	0.40	0.80	0.79	0.82	0.79
2,4-Dimethylpentane	ND	0.15	0.09	0.14	ND	0.62	0.56	0.59	0.62
Benzene	0.94	2.73	2.14	1.34	0.59	4.33	3.92	3.96	4.05
Cyclohexane	0.07	NDR	0.14	0.37	ND	0.36	0.30	0.30	0.28
2-Methylhexane	0.14	0.30	0.28	0.49	0.15	0.94	0.94	1.08	0.99
2,3-Dimethylpentane	NDR	NDR	NDR	0.20	ND	0.84	0.80	0.88	0.86
3-Methylhexane	NDR	NDR	NDR	NDR	NDR	1.11	0.98	NDR	1.04
2,2,4-Trimethylpentane	0.29	0.30	0.25	0.29	0.17	1.92	1.70	1.77	1.83
Heptane	0.23	0.61	0.48	0.96	0.26	0.91	0.83	1.42	0.93
Methylcyclohexane	0.15	0.54	0.39	0.76	0.08	0.44	0.37	0.41	0.40
2,5-Dimethylhexane	0.07	0.12	0.10	NDR	ND	0.26	0.24	0.28	0.25
2,4-Dimethylhexane	< DL	0.13	NDR	NDR	ND	0.31	0.30	0.33	0.31
2,3,4-Trimethylpentane	NDR	NDR	0.10	0.13	0.10	0.59	0.54	0.55	0.54
Toluene	1.79	4.97	2.88	3.53	1.36	9.76	9.56	9.74	9.70
2-Methylheptane	0.14	0.44	0.35	0.53	< DL	0.40	0.33	0.48	0.39
4-Methylheptane	0.07	0.21	0.17	0.26	0.10	0.17	0.16	0.20	0.19
3-Methylheptane	0.10	0.31	0.21	0.33	0.13	0.41	0.33	0.52	0.35
2,2,5-Trimethylhexane	0.09	0.08	0.08	0.07	ND	0.31	0.28	0.33	0.30
1-Octene	ND	0.18	0.12	0.20	0.17	ND	ND	0.37	ND
Octane	0.32	1.19	0.72	1.21	0.28	0.60	0.53	1.31	0.67
t-1,2-Dimethylcyclohexane	0.08	0.22	0.17	0.23	ND	0.11	0.08	0.10	0.11
Ethylbenzene	0.34	0.96	0.57	0.64	0.22	1.68	1.64	1.67	1.62
m,p-Xylene	1.12	4.40	2.42	2.46	0.59	5.24	5.04	5.21	5.09
Styrene	0.12	0.24	0.16	0.21	0.08	< DL	0.11	0.27	0.08
o-Xylene	0.46	2.23	1.17	0.99	0.23	1.78	1.71	1.78	1.69
Nonane	0.58	3.03	1.56	1.38	0.29	0.89	0.67	1.53	0.81
iso-Propylbenzene	0.05	0.17	0.10	0.08	< DL	0.17	0.16	0.18	0.16
n-Propylbenzene	0.12	0.38	0.22	0.18	0.05	0.39	0.37	0.36	0.35
3-Ethyltoluene	0.33	1.27	0.68	0.52	0.12	1.06	1.05	1.17	1.06
4-Ethyltoluene	0.17	0.62	0.34	0.26	< DL	0.49	0.49	0.53	0.53
1,3,5-Trimethylbenzene	0.25	1.22	0.61	0.40	0.07	0.39	0.41	0.54	0.47
2-Ethyltoluene	0.16	0.79	0.40	0.26	0.05	0.42	0.41	0.46	0.41
1,2,4-Trimethylbenzene	0.74	3.67	1.80	1.15	0.19	1.41	1.46	1.71	1.55
Decane	1.01	7.05	3.35	1.48	0.22	1.06	0.87	1.44	0.82
1,2,3-Trimethylbenzene	0.24	1.34	0.64	0.34	0.05	0.32	0.33	0.39	0.34
p-Cymene (1-Methyl-4-iso-propylbenzene)	0.05	0.23	0.12	0.08	0.05	0.10	0.11	0.11	0.08
1,3-Diethylbenzene	0.06	0.27	0.15	0.07	ND	0.09	0.10	0.14	0.09
1,4-Diethylbenzene	0.22	1.11	0.53	0.28	0.07	0.29	0.26	0.35	0.34
n-Butylbenzene	0.06	0.29	0.16	0.10	0.03	0.08	0.07	0.11	0.08
Undecane	2.36	19.6	8.80	1.78	0.18	1.07	0.86	1.41	0.78
Naphthalene	0.33	1.93	0.74	0.39	0.16	0.12	0.22	0.75	0.36
Dodecane	4.43	50.5	19.5	2.81	0.36	0.96	0.74	1.60	0.73
Hexylbenzene	0.16	NDR	0.47	0.18	ND	0.08	0.05	NDR	ND

< DL = Lower then Detectable Limits
ND = Not detected
NDR = Not detected due to "out of spec" ion ratio(s)
XS = Concentration exceeded detector range
Propane values corrected for Blank

TableA4 **VOCs Measured in Summa Canisters**

Burn Identification	Bm3Br1	Bm3Br1	Bm3Br1	Bm3Br1	Bm3Br1	Bm3Br1	Bm3Br1	Bm3Br1	Bm3aBr1
Location	S1A	S2A	S3A	S1C	S2C	S3C	UW1B	UW1B	DW1A
All values in µg/m³ Position	53°, 45m	110°, 45m	142°, 42m	341°, 35m	286°, 45m	238°, 25m	25°, 72m	25°, 72m	170°, 30m
TOTAL VOC (µg/m³)	116	373	77	192	222	208	106	191	144
Propene	1.32	1.36	0.51	0.60	0.76	0.54	1.44	0.51	2.13
Propane	2.94	3.58	2.60	3.88	4.37	4.11	8.07	4.37	12.4
Isobutane (2-Methylpropane)	0.49	2.28	0.48	1.36	1.31	1.21	4.72	1.25	6.37
1-Butene/2-Methylpropene	1.46	3.06	0.84	1.13	1.61	1.27	1.13	1.40	1.55
1,3-Butadiene	0.18	0.21	0.08	0.10	0.10	0.13	0.16	ND	0.31
Butane	1.22	9.23	1.14	3.99	2.85	2.73	9.01	2.55	12.0
Isoprene (2-Methyl-1,3-Butadiene)	0.80	1.22	0.52	1.31	1.18	1.02	2.62	0.99	0.95
t-2-Pentene	0.07	0.83	< DL	0.23	NDR	NDR	0.19	< DL	0.27
2-Methyl-2-Butene	0.20	1.20	0.12	0.34	0.23	0.15	0.24	0.11	0.28
2,2-Dimethylbutane	0.14	1.10	< DL	0.25	0.34	0.26	0.60	0.25	0.90
Cyclopentane	ND	0.92	0.08	0.27	0.16	0.19	0.48	0.15	0.59
2,3-Dimethylbutane	0.53	2.59	0.39	0.91	1.00	0.86	0.87	0.83	1.16
2-Methylpentane	3.57	12.9	2.63	4.51	7.50	5.94	NDR	6.29	3.98
3-Methylpentane	3.56	12.7	2.62	4.57	7.35	6.83	1.71	7.07	2.26
1-Hexene/2-Methyl-1-Pentene	0.89	2.63	0.61	0.92	1.65	1.40	0.32	1.27	0.61
Hexane	65.8	166	43.0	70.7	130	119	1.94	122	3.23
Methylcyclopentane	7.84	20.1	5.23	10.0	17.1	16.0	0.84	14.4	1.37
2,4-Dimethylpentane	0.41	1.72	0.28	0.78	0.84	0.76	0.65	0.66	0.81
Benzene	1.39	5.64	0.92	2.40	1.74	1.74	4.80	1.10	6.89
Cyclohexane	0.29	0.70	0.16	1.11	0.63	0.74	0.33	0.38	0.52
2-Methylhexane	0.53	1.91	0.33	1.89	1.16	1.12	1.04	0.70	1.42
2,3-Dimethylpentane	0.25	1.48	0.15	0.83	NDR	0.53	0.84	0.44	1.14
3-Methylhexane	NDR	1.97	NDR	1.73	NDR	1.03	NDR	0.68	NDR
2,2,4-Trimethylpentane	0.59	2.31	0.30	3.09	1.03	0.85	2.09	0.43	2.38
Heptane	0.40	1.31	0.25	3.25	1.02	1.16	0.92	0.46	1.27
Methylcyclohexane	NDR	0.42	0.13	2.98	0.76	0.88	0.41	0.16	0.69
2,5-Dimethylhexane	0.16	0.46	0.10	0.72	0.27	0.26	0.34	0.13	0.38
2,4-Dimethylhexane	0.20	0.57	0.10	0.72	0.38	0.35	0.46	0.19	0.70
2,3,4-Trimethylpentane	0.17	0.72	0.14	1.28	0.38	0.33	0.69	0.13	0.77
Toluene	7.06	34.7	4.36	14.1	11.0	11.7	13.7	8.40	19.9
2-Methylheptane	0.17	0.55	0.14	2.01	0.54	0.70	0.65	0.19	0.68
4-Methylheptane	1.28	2.19	0.65	2.11	2.05	2.30	0.16	1.49	0.30
3-Methylheptane	0.24	0.51	0.13	1.31	0.42	0.47	0.42	0.24	0.64
2,2,5-Trimethylhexane	0.19	0.42	0.07	0.95	0.26	0.22	0.44	0.09	0.47
1-Octene	ND	0.35	0.16	0.39	0.29	0.44	0.25	ND	0.19
Octane	0.27	0.66	0.23	3.87	0.91	1.21	0.65	0.28	0.86
t-1,2-Dimethylcyclohexane	ND	ND	ND	0.80	0.20	0.32	0.23	ND	0.17
Ethylbenzene	0.57	3.09	0.37	1.77	0.90	0.87	2.06	0.58	3.08
m,p-Xylene	1.75	12.2	1.21	7.01	3.03	3.03	6.24	1.72	8.55
Styrene	0.37	0.22	0.13	0.13	0.18	ND	0.15	< DL	0.28
o-Xylene	0.62	3.60	0.42	2.68	1.09	1.19	2.10	0.61	2.68
Nonane	0.27	0.73	0.24	3.17	0.89	1.14	0.85	0.37	0.74
iso-Propylbenzene	0.06	0.20	0.05	0.22	0.11	0.10	0.21	0.06	0.27
n-Propylbenzene	0.13	0.71	0.09	0.54	0.19	0.21	0.49	0.12	0.55
3-Ethyltoluene	0.44	2.06	0.22	1.62	0.55	0.49	1.42	0.22	1.77
4-Ethyltoluene	0.21	1.16	0.13	0.73	0.29	0.23	0.70	0.12	0.87
1,3,5-Trimethylbenzene	0.23	0.77	0.10	0.63	0.26	0.13	0.68	0.04	0.82
2-Ethyltoluene	0.17	0.70	0.09	0.67	0.24	0.24	0.57	0.12	0.67
1,2,4-Trimethylbenzene	0.71	3.02	0.35	2.39	0.91	0.59	2.47	0.23	2.80
Decane	0.34	0.97	0.24	2.59	1.02	1.16	1.27	0.47	0.93
1,2,3-Trimethylbenzene	0.15	0.57	0.09	0.55	0.23	0.16	0.49	0.07	0.58
p-Cymene (1-Methyl-4-iso-propylbenzene)	ND	0.09	ND	0.15	0.12	0.09	0.15	ND	0.14
1,3-Diethylbenzene	0.06	0.15	< DL	0.16	0.07	< DL	0.15	ND	0.31
1,4-Diethylbenzene	0.15	0.46	0.10	0.41	0.18	0.20	0.39	ND	0.50
n-Butylbenzene	0.04	0.12	0.04	0.11	0.07	0.06	0.14	0.03	0.15
Undecane	0.18	0.92	0.22	1.72	0.88	0.97	1.08	0.25	0.88
Naphthalene	0.27	0.16	0.11	0.09	0.22	0.12	0.58	< DL	0.86
Dodecane	0.24	0.87	0.26	1.39	1.01	1.09	0.91	0.23	0.66
Hexylbenzene	ND	ND	0.06	ND	ND	ND	ND	ND	ND

< DL = Lower then Detectable Limits
ND = Not detected
NDR = Not detected due to "out of spec" ion ratio(s)
XS = Concentration exceeded detector range
Propane values corrected for Blank

TableA5 **VOCs Measured in Summa Canisters**

Burn Identification	Bm3aBr1	Bm3aBr1	Bm3aBr1	Bm3aBr1	4Br1,2,3	Bm4Br1, 2 & 3	Bm4Br1, 2 & 3
Location	DW1B	DW2B	DW1C	UW1B	S1A	S1C	S2A
All values in µg/m³ Position	186°, 15m	189°, 30m	214°, 30m	25°, 72m	53°, 45m	341°, 35m	110°, 45m
TOTAL VOC (µg/m³)	120	135	127	142	107	111	107
Propene	1.90	2.46	2.02	3.29	2.43	1.39	2.19
Propane	11.4	12.2	11.5	12.8	8.41	8.27	9.90
Isobutane (2-Methylpropane)	6.58	5.45	5.80	5.75	3.41	3.17	3.43
1-Butene/2-Methylpropene	1.33	1.35	1.28	3.15	1.74	1.22	1.42
1,3-Butadiene	0.27	0.26	0.29	0.26	0.27	0.14	0.26
Butane	11.8	11.0	11.3	11.9	7.10	7.34	6.84
Isoprene (2-Methyl-1,3-Butadiene)	0.97	0.46	0.93	1.15	1.12	1.69	1.13
t-2-Pentene	0.26	0.27	0.23	0.34	0.17	0.20	0.15
2-Methyl-2-Butene	0.30	0.31	0.25	0.33	0.29	0.29	0.25
2,2-Dimethylbutane	0.74	0.85	0.79	0.97	0.48	0.52	0.53
Cyclopentane	0.58	0.66	0.60	0.67	0.37	0.36	0.30
2,3-Dimethylbutane	1.06	1.21	1.04	1.19	0.69	0.76	0.62
2-Methylpentane	3.24	3.82	3.49	NDR	NDR	2.22	2.16
3-Methylpentane	2.19	2.29	2.13	2.36	1.40	1.70	1.45
1-Hexene/2-Methyl-1-Pentene	0.61	0.72	0.58	0.71	0.42	0.79	0.42
Hexane	2.86	2.89	2.55	3.50	3.05	3.95	3.88
Methylcyclopentane	1.17	NDR	1.08	NDR	NDR	1.31	1.10
2,4-Dimethylpentane	0.72	0.75	0.62	0.78	0.45	0.55	0.39
Benzene	5.74	6.17	6.48	6.05	3.42	4.01	4.08
Cyclohexane	0.49	0.43	0.49	0.60	0.39	0.76	0.43
2-Methylhexane	1.58	1.51	1.25	1.46	0.97	1.21	0.74
2,3-Dimethylpentane	1.06	1.20	0.96	1.13	NDR	0.73	NDR
3-Methylhexane	1.56	NDR	NDR	NDR	NDR	1.25	NDR
2,2,4-Trimethylpentane	2.38	2.79	2.18	2.73	2.31	1.92	1.31
Heptane	1.11	1.33	1.07	1.65	1.05	1.96	0.92
Methylcyclohexane	0.69	0.69	0.61	0.97	0.62	1.63	0.50
2,5-Dimethylhexane	0.41	0.46	0.36	0.48	0.34	0.37	0.22
2,4-Dimethylhexane	0.57	0.95	0.64	NDR	0.45	0.42	0.31
2,3,4-Trimethylpentane	0.83	1.07	0.77	0.98	0.91	0.79	0.53
Toluene	13.7	19.5	17.0	18.3	8.25	11.3	9.27
2-Methylheptane	0.69	0.74	0.55	1.07	0.55	1.20	0.41
4-Methylheptane	0.28	NDR	0.23	NDR	0.23	0.39	0.25
3-Methylheptane	0.55	0.67	0.64	0.86	0.40	0.69	0.31
2,2,5-Trimethylhexane	0.46	0.62	0.43	0.60	0.57	0.54	0.32
1-Octene	ND	0.18	0.20	ND	0.40	0.59	0.50
Octane	0.52	0.91	0.70	1.29	0.80	2.22	0.84
t-1,2-Dimethylcyclohexane	0.10	0.14	0.11	0.23	ND	0.42	ND
Ethylbenzene	1.73	2.28	2.32	2.59	1.43	1.70	1.36
m,p-Xylene	4.77	7.54	7.38	8.27	4.53	5.94	4.25
Styrene	0.07	0.46	0.26	0.27	0.19	0.21	0.27
o-Xylene	2.25	2.70	2.32	2.90	1.65	2.24	1.46
Nonane	0.28	0.72	0.64	1.21	2.15	2.07	2.57
iso-Propylbenzene	0.22	0.21	0.23	0.27	0.21	0.24	0.20
n-Propylbenzene	0.20	0.55	0.51	0.61	0.59	0.58	0.46
3-Ethyltoluene	0.82	1.84	1.61	1.87	1.88	1.67	1.52
4-Ethyltoluene	0.20	0.88	0.75	0.93	0.85	0.85	0.67
1,3,5-Trimethylbenzene	1.20	0.89	0.74	0.87	0.95	0.90	0.82
2-Ethyltoluene	0.51	0.67	0.60	0.73	0.73	0.69	0.60
1,2,4-Trimethylbenzene	1.56	2.80	2.40	2.82	2.59	2.57	2.18
Decane	0.15	0.63	0.74	1.15	9.51	1.55	8.87
1,2,3-Trimethylbenzene	0.46	0.54	0.52	0.58	0.53	0.56	0.47
p-Cymene (1-Methyl-4-iso-propylbenzene)	0.19	0.09	0.09	0.16	0.18	0.15	0.13
1,3-Diethylbenzene	0.12	0.17	0.29	0.26	0.19	0.20	0.18
1,4-Diethylbenzene	NDR	0.45	0.49	0.51	0.44	0.46	0.45
n-Butylbenzene	0.04	0.13	0.13	0.14	0.15	0.14	0.16
Undecane	0.08	0.54	0.66	1.05	6.47	1.33	4.99
Naphthalene	0.08	0.82	0.75	0.73	0.44	0.60	0.69
Dodecane	ND	0.50	0.51	0.97	4.04	1.38	3.48
Hexylbenzene	ND	ND	0.06	ND	0.08	0.11	NDR

< DL = Lower then Detectable Limits
ND = Not detected
NDR = Not detected due to "out of spec" ion ratio(s)
XS = Concentration exceeded detector range
Propane values corrected for Blank

TableA6 **VOCs Measured in Summa Canisters**

Burn Identification	Bm4Br1, 2 & 3	Bm4Br1, 2 & 3	Bm4Br1, 2 & 3	Bm4Br1, 2 & 3	Bm4Br1	Bm4Br1	Bm4Br1
Location	S2C	S3A	S3C	UW1B	DW1A	DW1B	DW2B
All values in µg/m³ Position	286°, 45m	142°, 42m	238°, 25m	25°, 72m	170°, 30m	186°, 15m	189°, 30m
TOTAL VOC (µg/m³)	91	92	114	118	117	143	116
Propene	1.87	2.03	1.84	3.36	3.26	2.81	2.83
Propane	10.4	10.3	9.79	9.63	11.9	12.2	11.9
Isobutane (2-Methylpropane)	3.63	3.47	3.43	3.49	4.46	4.63	4.75
1-Butene/2-Methylpropene	1.34	1.35	1.45	2.15	0.87	0.85	0.76
1,3-Butadiene	0.24	0.23	0.19	0.19	0.21	0.19	0.20
Butane	7.71	6.85	7.33	8.19	8.98	10.1	9.94
Isoprene (2-Methyl-1,3-Butadiene)	1.21	0.98	1.15	1.73	0.52	0.68	0.64
t-2-Pentene	0.15	0.13	0.15	0.31	0.17	0.24	0.22
2-Methyl-2-Butene	0.21	0.23	0.24	0.51	0.19	0.32	0.26
2,2-Dimethylbutane	0.57	0.59	0.62	0.53	0.68	0.72	0.69
Cyclopentane	0.38	0.32	0.38	0.41	0.45	0.59	0.51
2,3-Dimethylbutane	0.71	0.64	0.62	0.93	0.75	0.85	0.80
2-Methylpentane	2.43	2.23	2.56	2.23	2.63	2.95	2.66
3-Methylpentane	1.61	1.40	1.64	1.77	1.95	2.15	2.01
1-Hexene/2-Methyl-1-Pentene	0.38	0.39	0.39	0.47	0.29	0.34	0.28
Hexane	3.93	2.97	4.53	3.74	3.19	4.57	3.48
Methylcyclopentane	1.20	0.90	1.31	1.23	1.16	1.37	1.21
2,4-Dimethylpentane	0.46	0.40	0.39	0.68	0.46	0.49	0.49
Benzene	3.99	3.86	4.18	3.93	4.40	5.02	4.79
Cyclohexane	0.37	0.45	0.49	0.46	0.50	0.55	0.49
2-Methylhexane	0.83	0.83	0.89	1.03	0.98	1.17	0.99
2,3-Dimethylpentane	0.57	0.59	0.58	0.88	0.63	0.75	0.67
3-Methylhexane	NDR	NDR	NDR	NDR	NDR	NDR	NDR
2,2,4-Trimethylpentane	1.21	1.28	1.10	4.25	1.22	1.51	1.33
Heptane	1.01	0.89	1.17	1.07	1.18	1.60	1.07
Methylcyclohexane	0.61	0.48	0.75	0.70	0.93	1.09	0.71
2,5-Dimethylhexane	0.24	0.24	0.25	0.57	0.27	0.31	0.24
2,4-Dimethylhexane	0.23	0.28	0.36	0.60	0.32	0.43	0.33
2,3,4-Trimethylpentane	0.42	0.51	0.46	1.78	0.52	0.56	0.49
Toluene	9.41	8.42	9.87	9.91	12.7	14.4	15.1
2-Methylheptane	0.50	0.41	0.57	0.62	0.72	1.02	0.59
4-Methylheptane	0.24	0.18	0.27	0.26	0.27	0.39	0.21
3-Methylheptane	0.41	0.30	0.44	0.55	0.61	0.65	0.46
2,2,5-Trimethylhexane	0.25	0.31	0.25	1.47	0.28	0.33	0.30
1-Octene	0.15	0.48	0.50	0.29	ND	0.24	ND
Octane	0.85	0.80	1.09	1.31	1.41	1.81	1.03
t-1,2-Dimethylcyclohexane	0.17	ND	ND	ND	0.31	0.35	0.21
Ethylbenzene	1.30	1.29	1.38	1.50	1.67	2.15	1.91
m,p-Xylene	4.15	4.13	4.51	4.95	5.50	8.75	6.01
Styrene	0.19	0.25	0.24	0.28	0.26	0.40	0.29
o-Xylene	1.50	1.51	1.63	1.92	2.00	3.32	2.05
Nonane	0.86	0.86	2.88	1.58	1.89	2.15	1.12
iso-Propylbenzene	0.16	0.17	0.21	0.25	0.21	0.26	0.18
n-Propylbenzene	0.36	0.43	0.44	0.70	0.57	0.65	0.51
3-Ethyltoluene	1.03	1.28	1.27	2.18	1.66	1.92	1.44
4-Ethyltoluene	0.55	0.62	0.61	1.09	0.83	0.93	0.71
1,3,5-Trimethylbenzene	0.49	0.63	0.71	1.15	0.92	1.08	0.71
2-Ethyltoluene	0.41	0.50	0.56	0.79	0.70	0.79	0.55
1,2,4-Trimethylbenzene	1.50	1.92	1.85	3.21	2.58	3.12	2.11
Decane	0.92	1.57	9.82	2.18	2.20	2.58	1.15
1,2,3-Trimethylbenzene	0.35	0.42	0.46	0.64	0.64	0.81	0.48
p-Cymene (1-Methyl-4-iso-propylbenzene)	0.14	0.14	0.17	0.13	0.23	0.26	0.18
1,3-Diethylbenzene	0.13	0.17	0.16	0.24	0.13	0.18	0.12
1,4-Diethylbenzene	0.30	0.40	0.39	0.58	0.48	0.69	0.36
n-Butylbenzene	0.08	0.12	0.12	0.14	0.14	1.89	0.10
Undecane	0.94	2.00	6.58	2.42	2.96	4.00	1.14
Naphthalene	0.46	0.58	0.62	0.82	0.96	1.32	0.79
Dodecane	1.06	2.83	4.49	2.40	4.36	6.23	1.50
Hexylbenzene	0.08	NDR	0.11	0.10	ND	ND	ND

< DL = Lower then Detectable Limits
ND = Not detected
NDR = Not detected due to "out of spec" ion ratio(s)
XS = Concentration exceeded detector range
Propane values corrected for Blank

TableA7 **VOCs Measured in Summa Canisters**

Burn Identification	Bm4Br1	Bm4Br1	Bm4Br2	Bm4Br2	Bm4Br2	Bm4Br2	Bm4Br2	Bm4Br3	Bm4Br3
Location	DW1C	UW1B	DW1A	DW1B	DW2B	DW1C	UW1B	DW1A	DW1B
All values in µg/m³ Position	214°, 30m	25°, 72m	170°, 30m	186°, 15m	189°, 30m	214°, 30m	25°, 72m	170°, 30m	186°, 15m
TOTAL VOC (µg/m³)	**197**	**224**	**47**	**440**	**417**	**80**	**47**	**32**	**254**
Propene	2.82	4.55	0.81	1.87	1.45	0.83	1.62	0.77	1.08
Propane	11.8	12.2	6.81	7.63	9.65	7.45	6.60	2.08	4.17
Isobutane (2-Methylpropane)	5.60	5.01	2.16	2.36	5.04	2.47	2.67	0.61	0.61
1-Butene/2-Methylpropene	0.82	2.59	1.19	1.05	1.55	0.90	2.99	0.71	1.00
1,3-Butadiene	0.19	0.39	0.14	0.66	0.35	0.23	0.15	0.12	0.35
Butane	15.6	13.7	3.95	4.62	22.7	4.71	4.91	1.49	1.49
Isoprene (2-Methyl-1,3-Butadiene)	0.78	1.14	1.70	2.18	1.90	2.11	3.45	1.09	1.40
t-2-Pentene	0.69	0.78	ND	0.14	1.67	0.10	0.12	ND	NDR
2-Methyl-2-Butene	1.07	1.38	0.13	0.20	2.58	0.18	NDR	0.11	0.10
2,2-Dimethylbutane	1.21	0.69	0.18	0.24	2.20	0.22	0.18	0.13	0.25
Cyclopentane	1.21	0.57	0.09	0.25	2.14	0.14	0.14	0.10	0.15
2,3-Dimethylbutane	1.70	2.01	0.23	0.34	3.12	0.29	0.20	0.15	0.19
2-Methylpentane	5.25	4.04	0.80	1.41	10.6	1.12	NDR	NDR	NDR
3-Methylpentane	3.69	2.82	0.52	0.90	6.45	0.67	0.58	0.27	0.58
1-Hexene/2-Methyl-1-Pentene	0.54	0.73	< DL	0.49	0.94	0.36	0.42	< DL	0.36
Hexane	5.77	3.86	1.51	2.99	9.02	1.56	1.42	0.60	1.44
Methylcyclopentane	1.97	1.83	0.34	0.83	2.65	0.46	NDR	NDR	NDR
2,4-Dimethylpentane	1.00	1.77	0.19	0.24	1.60	0.24	ND	ND	0.19
Benzene	7.93	4.60	2.41	9.67	12.7	3.70	2.28	2.80	6.23
Cyclohexane	0.57	0.59	0.14	0.85	0.78	0.38	0.18	NDR	0.76
2-Methylhexane	1.47	1.97	0.34	1.19	2.61	0.68	NDR	NDR	1.02
2,3-Dimethylpentane	1.25	1.95	NDR	0.43	2.25	NDR	0.17	NDR	NDR
3-Methylhexane	1.70	2.06	NDR	NDR	NDR	NDR	NDR	NDR	NDR
2,2,4-Trimethylpentane	2.18	16.2	0.82	0.66	3.77	0.90	0.40	0.30	0.32
Heptane	1.58	2.04	0.55	2.96	2.89	1.36	0.60	0.36	2.50
Methylcyclohexane	0.77	1.65	0.26	3.12	1.58	1.04	0.17	0.15	2.72
2,5-Dimethylhexane	0.39	1.99	0.16	0.39	0.73	0.26	NDR	NDR	0.27
2,4-Dimethylhexane	0.45	1.86	0.17	0.45	1.12	0.29	NDR	NDR	0.47
2,3,4-Trimethylpentane	0.77	7.26	0.35	0.32	1.27	0.39	NDR	0.09	0.15
Toluene	27.2	17.1	2.97	12.3	55.2	4.50	2.53	3.56	7.22
2-Methylheptane	0.91	1.66	0.27	2.83	1.83	0.90	0.38	0.18	1.88
4-Methylheptane	0.36	0.57	0.11	0.73	0.55	0.17	ND	ND	0.45
3-Methylheptane	0.72	1.33	0.18	1.51	1.12	0.49	0.16	NDR	1.05
2,2,5-Trimethylhexane	0.45	5.61	0.27	0.26	0.69	0.27	0.06	0.08	NDR
1-Octene	ND	ND	0.41	0.70	0.38	0.51	0.53	0.19	0.40
Octane	1.41	2.82	0.62	7.38	3.18	1.80	0.54	0.44	4.67
t-1,2-Dimethylcyclohexane	0.24	0.62	0.08	1.49	0.62	0.35	ND	NDR	1.04
Ethylbenzene	3.76	2.82	0.41	3.14	5.92	0.81	0.39	0.50	2.24
m,p-Xylene	13.4	9.92	1.16	16.3	26.1	2.86	1.03	1.51	11.7
Styrene	0.33	0.36	0.12	1.18	0.41	0.48	0.10	0.16	0.54
o-Xylene	3.90	4.09	0.51	7.75	7.99	1.40	0.43	0.68	5.31
Nonane	1.34	3.06	0.62	15.3	5.32	1.88	0.40	0.49	10.0
iso-Propylbenzene	0.26	0.57	0.06	0.72	0.50	0.14	0.05	0.06	0.50
n-Propylbenzene	0.87	1.83	0.16	1.64	1.59	0.30	0.09	0.12	1.10
3-Ethyltoluene	2.40	6.12	0.40	5.33	4.81	0.89	0.21	0.30	3.53
4-Ethyltoluene	1.35	2.93	0.20	2.64	2.45	0.44	0.10	0.17	1.67
1,3,5-Trimethylbenzene	1.23	3.24	0.23	5.42	3.05	0.96	0.10	0.18	3.35
2-Ethyltoluene	0.86	2.21	0.18	3.26	2.01	0.44	0.11	0.16	2.12
1,2,4-Trimethylbenzene	4.22	8.99	0.71	16.5	9.70	1.83	0.38	0.56	10.2
Decane	1.47	2.55	0.79	31.0	9.64	2.33	0.40	0.49	18.1
1,2,3-Trimethylbenzene	0.77	1.63	0.19	5.71	2.60	0.57	0.09	0.18	3.61
p-Cymene (1-Methyl-4-iso-propylbenzene)	0.24	0.36	0.10	1.12	0.47	0.22	0.09	NDR	0.66
1,3-Diethylbenzene	0.17	0.55	0.06	1.03	0.47	0.12	< DL	0.05	0.73
1,4-Diethylbenzene	0.62	1.26	0.21	5.09	2.12	0.48	0.15	0.15	3.12
n-Butylbenzene	0.21	0.26	0.07	1.22	0.54	0.18	ND	0.08	0.81
Undecane	1.43	2.07	1.52	74.6	22.1	4.60	0.70	0.97	41.7
Naphthalene	1.16	1.21	0.32	11.5	2.85	1.26	0.30	3.93	5.31
Dodecane	1.48	1.98	3.03	136	37.2	7.50	1.04	1.88	74.6
Hexylbenzene	0.14	ND	ND	3.80	0.75	0.40	ND	0.10	1.43

< DL = Lower then Detectable Limits
ND = Not detected
NDR = Not detected due to "out of spec" ion ratio(s)
XS = Concentration exceeded detector range
Propane values corrected for Blank

TableA8 **VOCs Measured in Summa Canisters**

Burn Identification	Bm4Br3	Bm4Br3	Bm4Br3	Bm5Br1	Bm5Br1	Bm5Br1	Bm5Br1	Bm5Br1	Bm5Br1
Location	DW2B	DW1C	UW1B	DW1A	DW1B	DW2B	DW1C	S1A	S2A
All values in µg/m³ Position	189°, 30m	214°, 30m	25°, 72m	170°, 30m	186°, 15m	189°, 30m	214°, 30m	53°, 45m	110°, 45m
TOTAL VOC (µg/m³)	65	250	18	17	112	21	29	11	11
Propene	0.87	1.71	0.29	0.47	1.45	0.54	0.57	0.83	0.63
Propane	6.51	2.22	2.50	1.47	2.35	1.14	1.90	1.14	1.28
Isobutane (2-Methylpropane)	0.86	0.62	0.71	0.30	0.34	0.25	0.39	0.27	0.26
1-Butene/2-Methylpropene	1.09	1.32	0.57	0.40	1.23	0.73	0.71	0.69	0.72
1,3-Butadiene	0.22	0.58	ND	0.08	0.30	0.11	0.10	0.14	0.09
Butane	2.33	1.77	1.63	0.87	1.07	0.79	1.38	0.82	0.75
Isoprene (2-Methyl-1,3-Butadiene)	0.52	1.52	2.01	0.27	0.46	0.20	0.40	0.35	0.33
t-2-Pentene	0.09	0.11	ND	ND	0.10	ND	NDR	ND	ND
2-Methyl-2-Butene	0.14	0.14	0.06	ND	0.12	ND	0.13	0.07	0.06
2,2-Dimethylbutane	0.18	0.24	0.14	< DL	< DL	< DL	NDR	< DL	< DL
Cyclopentane	0.16	0.14	ND	ND	0.09	ND	0.07	ND	ND
2,3-Dimethylbutane	0.20	0.15	0.11	ND	0.13	0.09	0.13	0.06	0.07
2-Methylpentane	NDR	NDR	0.38	0.19	NDR	NDR	NDR	0.12	NDR
3-Methylpentane	0.59	0.50	0.25	0.14	0.30	0.17	NDR	0.10	NDR
1-Hexene/2-Methyl-1-Pentene	0.26	0.67	< DL	< DL	0.31	< DL	0.24	ND	< DL
Hexane	1.16	1.17	0.46	0.27	0.79	0.42	0.42	0.17	0.19
Methylcyclopentane	0.31	NDR	0.14	NDR	NDR	0.18	NDR	0.08	0.06
2,4-Dimethylpentane	0.13	0.15	0.07	ND	0.12	ND	0.13	ND	ND
Benzene	3.21	8.28	0.82	1.88	4.10	2.42	1.10	0.93	0.67
Cyclohexane	0.30	0.50	ND	0.08	0.40	0.14	0.19	ND	NDR
2-Methylhexane	0.69	0.77	0.17	0.12	NDR	0.23	0.30	ND	ND
2,3-Dimethylpentane	NDR	NDR	NDR	ND	0.20	< DL	NDR	< DL	ND
3-Methylhexane	NDR	NDR	NDR	0.12	NDR	NDR	NDR	NDR	NDR
2,2,4-Trimethylpentane	ND	NDR	0.13	0.21	0.46	0.33	0.67	0.34	0.23
Heptane	1.60	1.90	0.24	0.29	1.40	0.48	0.63	< DL	0.19
Methylcyclohexane	1.07	2.11	0.07	0.20	1.37	0.42	0.50	0.08	0.08
2,5-Dimethylhexane	0.15	0.23	ND	NDR	NDR	0.08	0.16	0.05	ND
2,4-Dimethylhexane	0.19	0.30	ND	NDR	NDR	0.09	0.12	< DL	ND
2,3,4-Trimethylpentane	0.10	ND	ND	0.09	0.25	0.14	0.29	0.12	0.09
Toluene	3.76	7.43	1.28	1.48	3.94	1.73	1.44	0.99	0.85
2-Methylheptane	0.85	1.76	ND	0.18	1.00	0.32	0.37	< DL	ND
4-Methylheptane	0.29	0.45	ND	0.05	0.25	0.11	0.11	ND	ND
3-Methylheptane	0.62	0.99	ND	0.11	0.58	0.22	0.25	0.06	ND
2,2,5-Trimethylhexane	0.09	0.10	ND	0.07	0.12	0.08	0.17	0.11	0.06
1-Octene	0.21	0.65	0.16	0.12	0.27	ND	0.20	0.15	0.32
Octane	1.97	4.74	0.26	0.42	2.11	0.66	0.72	0.15	0.16
t-1,2-Dimethylcyclohexane	0.46	1.03	ND	0.09	0.48	0.16	0.16	ND	ND
Ethylbenzene	0.94	2.39	0.22	0.22	0.96	0.30	0.30	0.18	0.15
m,p-Xylene	4.00	12.4	0.55	0.70	4.15	1.07	1.21	0.55	0.45
Styrene	< DL	0.53	< DL	ND	0.22	ND	ND	ND	ND
o-Xylene	2.11	5.64	0.19	0.35	2.05	0.55	0.53	0.22	0.20
Nonane	2.91	11.3	0.19	0.67	3.27	1.08	0.88	0.16	0.20
iso-Propylbenzene	0.22	0.57	0.04	0.05	0.19	0.07	0.07	< DL	< DL
n-Propylbenzene	0.34	1.28	0.06	0.09	0.42	0.12	0.14	0.06	< DL
3-Ethyltoluene	1.10	4.08	0.11	0.13	1.23	0.18	0.41	0.15	0.13
4-Ethyltoluene	0.41	1.89	0.08	< DL	0.60	< DL	0.21	< DL	< DL
1,3,5-Trimethylbenzene	1.23	3.67	0.07	< DL	1.07	ND	0.29	0.04	0.05
2-Ethyltoluene	0.75	2.46	0.06	0.10	0.72	0.15	0.21	0.07	0.06
1,2,4-Trimethylbenzene	2.78	11.4	0.19	0.12	3.41	0.13	0.84	0.18	0.20
Decane	3.11	21.1	0.20	0.89	5.77	1.39	1.02	0.16	0.23
1,2,3-Trimethylbenzene	1.17	4.17	0.06	0.05	1.15	0.06	0.27	< DL	0.05
p-Cymene (1-Methyl-4-iso-propylbenzene)	0.32	0.79	ND	ND	0.21	ND	0.08	ND	ND
1,3-Diethylbenzene	0.19	0.72	ND	ND	0.24	ND	0.08	ND	ND
1,4-Diethylbenzene	0.42	3.35	0.08	0.07	0.98	NDR	0.24	< DL	ND
n-Butylbenzene	0.12	0.82	0.05	0.04	0.27	0.05	0.07	ND	ND
Undecane	3.25	42.2	0.23	1.18	15.7	1.60	1.85	0.10	0.19
Naphthalene	0.32	3.95	0.13	0.05	2.31	0.14	0.25	0.10	0.04
Dodecane	2.71	60.0	0.37	0.62	36.7	0.45	3.18	0.15	0.16
Hexylbenzene	ND	0.98	0.10	ND	0.62	ND	0.09	ND	ND

< DL = Lower than Detectable Limits
ND = Not detected
NDR = Not detected due to "out of spec" ion ratio(s)
XS = Concentration exceeded detector range
Propane values corrected for Blank

TableA9 **VOCs Measured in Summa Canisters**

Burn Identification	Bm5Br1	Bm5Br1	Bm5Br1	Bm5Br1	Bm5Br1
Location	S3A	S1C	S2C	S3C	UW1B
All values in µg/m³ Position	142°, 42m	341°, 35m	286°, 45m	238°, 25m	25°, 72m
TOTAL VOC (µg/m³)	8	56	25	23	5
Propene	0.45	0.52	0.43	0.75	0.15
Propane	1.52	1.50	1.80	1.73	0.96
Isobutane (2-Methylpropane)	0.29	0.73	0.57	0.38	0.21
1-Butene/2-Methylpropene	0.43	0.68	0.47	1.41	< DL
1,3-Butadiene	< DL	ND	ND	ND	ND
Butane	0.84	4.39	2.18	1.34	0.60
Isoprene (2-Methyl-1,3-Butadiene)	0.07	0.40	0.20	0.31	0.23
t-2-Pentene	ND	0.25	NDR	NDR	ND
2-Methyl-2-Butene	ND	0.17	0.09	0.11	ND
2,2-Dimethylbutane	< DL	< DL	< DL	NDR	< DL
Cyclopentane	ND	0.14	0.14	0.05	ND
2,3-Dimethylbutane	0.06	0.46	0.30	0.13	0.06
2-Methylpentane	0.17	0.82	0.56	NDR	0.13
3-Methylpentane	0.10	0.58	0.41	NDR	0.09
1-Hexene/2-Methyl-1-Pentene	ND	< DL	< DL	0.25	< DL
Hexane	0.16	1.29	0.59	0.38	0.15
Methylcyclopentane	0.08	0.64	0.27	0.19	ND
2,4-Dimethylpentane	ND	0.36	0.23	0.12	ND
Benzene	0.71	1.33	0.93	1.10	0.47
Cyclohexane	NDR	0.71	0.13	NDR	NDR
2-Methylhexane	ND	0.96	0.33	0.33	ND
2,3-Dimethylpentane	ND	0.54	0.27	NDR	ND
3-Methylhexane	NDR	0.92	0.31	NDR	ND
2,2,4-Trimethylpentane	0.19	3.03	1.04	0.86	0.18
Heptane	< DL	2.21	0.48	0.56	< DL
Methylcyclohexane	0.10	2.20	0.38	0.47	ND
2,5-Dimethylhexane	ND	0.49	0.16	0.15	ND
2,4-Dimethylhexane	ND	0.47	0.18	NDR	ND
2,3,4-Trimethylpentane	0.06	1.28	0.44	0.39	0.09
Toluene	0.76	4.07	2.49	1.45	0.52
2-Methylheptane	< DL	1.34	0.27	0.38	ND
4-Methylheptane	ND	0.39	0.09	0.09	ND
3-Methylheptane	ND	0.78	0.25	0.25	ND
2,2,5-Trimethylhexane	0.05	0.80	0.26	0.21	0.04
1-Octene	ND	0.18	ND	0.13	ND
Octane	0.20	2.63	0.58	0.66	< DL
t-1,2-Dimethylcyclohexane	ND	0.60	0.15	0.14	ND
Ethylbenzene	0.12	0.74	0.28	0.26	0.07
m,p-Xylene	0.27	2.58	0.70	0.96	0.13
Styrene	ND	ND	ND	ND	ND
o-Xylene	0.14	1.20	0.33	0.41	0.06
Nonane	0.21	2.00	0.58	0.63	0.09
iso-Propylbenzene	< DL	0.11	< DL	0.05	ND
n-Propylbenzene	< DL	0.28	0.10	0.12	< DL
3-Ethyltoluene	ND	0.37	< DL	0.29	ND
4-Ethyltoluene	ND	0.25	< DL	0.15	< DL
1,3,5-Trimethylbenzene	ND	ND	ND	0.13	ND
2-Ethyltoluene	ND	0.25	< DL	0.14	ND
1,2,4-Trimethylbenzene	ND	0.14	< DL	0.47	ND
Decane	0.20	1.08	0.52	0.58	0.05
1,2,3-Trimethylbenzene	ND	< DL	ND	0.11	ND
p-Cymene (1-Methyl-4-iso-propylbenzene)	ND	ND	ND	ND	ND
1,3-Diethylbenzene	ND	ND	ND	< DL	ND
1,4-Diethylbenzene	ND	ND	ND	0.11	ND
n-Butylbenzene	ND	ND	ND	0.03	ND
Undecane	0.07	0.48	0.15	0.48	0.05
Naphthalene	0.03	< DL	< DL	0.05	0.03
Dodecane	ND	ND	ND	0.24	ND
Hexylbenzene	ND	ND	ND	ND	ND

< DL = Lower then Detectable Limits
ND = Not detected
NDR = Not detected due to "out of spec" ion ratio(s)
XS = Concentration exceeded detector range
Propane values corrected for Blank