SURVEY REPORT.

CONTROL TECHNOLOGY EVALUATION FOR CONTROLLING WORKER EXPOSURE TO ASPHALT FUMES FROM ROOFING KETTLES KETTLE OPERATED USING AN AFTERBURNER SYSTEM

at

Glenwood Elementary School
San Rafael, California

REPORT WRITTEN BY
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FACILITIES SURVEYED	Glenwood Elementary School 25 West Castlewood Dr San Rafael, California
SIC CODE	1761
SURVEY DATES	July 16 through July 25, 2002
SURVEY CONDUCTED BY	David A Marlow
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SUMMARY

From July 16 through 25, 2002, a field survey was conducted at Glenwood Elementary School in San Rafael, California where a built up asphalt roof was being installed to replace the old roof The school was under going a complete renovation A separate crew had previously removed the old roof, and a different crew installed the new roof The survey was conducted to evaluate the effectiveness of using an afterburner system with a safety loading door fitted to an asphalt kettle to reduce worker exposure to asphalt fumes

Personal breathing zone and area air samples were collected and analyzed for total particulate (TP), benzene soluble fraction (BSF) of the TP, and total polycyclic aromatic compounds (PAC) These three analyses were chosen to represent indices of exposure to asphalt fumes Air samples were collected with the afterburner on and kettle lid closed and afterburner off and kettle lid closed Air samples were collected on the kettle operator and two roof level workers, area air samples were collected around the four corners of the kettle

The kettle operator's exposures to TP, BSF, and total PAC were all reduced when the afterburner was on and the kettle lid was closed when compared to when the afterburner was off and the kettle lid was closed Reductions in exposures for the kettle operator of 23%, 54%, and 43% for TP, BSF, and total PAC were measured Reductions of 33%, 66%, and 72% in TP, BSF, and total PAC were measured for the area air samples collected around the kettle For the roof level workers, exposures to TP, BSF, and total PAC were reduced 33%, 27%, and 23%, respectively Only the reduction of 66% for BSF seen in the area air samples collected around the kettle was statistically significant None of the reductions measured for the kettle operator or the roof level workers were statistically significant ($p \leq 0.05$) The greatest reductions in asphalt fume exposure occurred when the afterburners were on and the kettle lid was closed Using the afterburner system with the kettle lid closed provided the most protection from asphalt fume exposure, particularly for the kettle operator The kettle operator loaded all the asphalt into the kettle by opening the kettle lid instead of using the safety loading door allowing asphalt fumes to be emitted during this work activity The kettle operator also spent half of the work day working on the roof, getting a similar asphalt fume exposure as the other roof level workers These work practices may have had a negative effect on the percent reductions measured

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), a federal agency located in the Centers for Disease Control and Prevention (CDC) under the Department of Health and Human Services, was established by the Occupational Safety and Health Act of 1970 This legislation mandated NIOSH to conduct research and education programs separate from the standard setting and enforcement functions conducted by the Occupational Safety and Health Administration (OSHA) in the Department of Labor An important area of NIOSH research deals with methods for controlling occupational exposure to potential biological, chemical, and physical hazards

The Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology has been given the lead within NIOSH to study the engineering aspects relevant to the control of hazards in the workplace Since 1976, EPHB has assessed control technology found within selected industries or used for common industrial processes EPHB has also designed new control systems where current industry control technology was insufficient The objective of these studies was to document and evaluate effective control techniques (e g , isolation or the use of local ventilation) that minimized the risk of potential health hazards and created an awareness of the usefulness and availability of effective hazard control measures

One industry identified for EPHB control studies is asphalt roofing Epidemiologic studies of roofers have demonstrated an excess of lung, bladder, renal, brain, liver, and digestive system cancers among roofers or other occupations with the potential for exposure to asphalt [1-16] It is unclear to what extent these findings may be attributable to asphalt fume exposure Roofers in the past have also been exposed to coal tar and asbestos which are known carcinogens

Based on the epidemiological data, researchers from EPHB developed a project to evaluate engineering controls in the asphalt roofing industry Due to the high asphalt temperatures used in the roofing process, roofing kettle operators may be at higher risk of asphalt fume exposure than workers in any other industry or trade using asphalt This project evaluates existing engineering controls for asphalt fume exposures to roofing kettle operators and, if necessary, redesigns those controls to reduce operator exposure In 1990, an estimated 46,000 roofing workers were exposed to asphalt fumes in the United States Only 10% of those workers were covered under a collective bargaining agreement These workers were employed primarily by small contractors who generally lack detailed occupational safety and health programs or a designated occupational safety and health expert – about 90% of roofing contractors have fewer than 20 employees Studying ways to reduce exposure to these construction workers addresses item 10 2 of the Healthy People 2000 Objectives, the NIOSH National Occupational Research Agenda (NORA), and OSHA priorities [17-19]

While this project concerns itself primarily with the reduction of asphalt fume exposure to kettle operators, parallel studies in cooperation with the EPHB study provide an in-depth examination of asphalt fume exposures to workers on the roof during hot asphalt application There are three

NIOSH studies examining engineering controls, blood and urine biomarkers, and medical effects due to asphalt fume exposure and a Harvard University study examining urine biomarkers and PAC/Pyrene exposure

Kettle operators are responsible for maintaining the appropriate supply of hot asphalt at the correct temperature for application on the roof during construction of built-up roofs (BUR) BURs are layers or plies of fiberglass felt sealed together with hot asphalt The layers provide protection against moisture penetration and, combined with the asphalt's ability to seal itself, makes BUR an excellent waterproofing system [20] Roofing kettles are steel containers used to heat and store hot asphalt until needed for application on the roof They vary in size from 150 to 1500 gallons They are equipped with a positive displacement pump, powered by a gasoline engine, which recirculates the hot asphalt in the kettle and transfers the hot asphalt, via a "hot pipe," to the roof Roofing kettles are normally equipped with one or two propane fired burners for heating the asphalt The propane burners exhaust into fire-tubes which are submerged in the asphalt within the kettle These tubes direct the hot combustion gases through one or two passes running the length of the kettle, transferring heat energy to the asphalt before being released to the atmosphere The asphalt temperature is controlled by throttling the propane supply to the burner(s) The throttle valve is manually operated by the kettle operator or hydraulically actuated via a thermostat The kettle is usually located at ground level during the roofing operation When additional asphalt is needed by the workers on the roof, hot asphalt is pumped from the kettle through the hot pipe to the roof level for application Activation of the pump may be done manually by the kettle operator or remotely from the roof by a pull rope attached to the kettle The recirculating/transfer pump is normally operated only during the transfer of hot asphalt to the roof

Roofing asphalt may be delivered to the work site in solid kegs or in tanker trucks When tanker trucks are used, a roofing kettle may not be necessary unless additional heating is required The more traditional method is to deliver the asphalt in solid, paper-wrapped kegs which weigh approximately 100 pounds During loading, the kettle operator must remove the paper wrapping and chop the solid asphalt keg into smaller, more manageable pieces These pieces are manually loaded into the kettle through a raised kettle lid or, when available, through a safety loading door designed to reduce worker exposure to asphalt fumes and prevent the operator from being splashed with hot asphalt In addition to loading asphalt, the kettle operator periodically opens the lid to remove impurities which tend to accumulate on the surface of the hot asphalt, this is called skimming

The equiviscous temperature (EVT) is the application temperature (EVT varies each production batch) at which optimum wetting and adhesive qualities of the roofing asphalt are obtained The asphalt temperature in the kettle is maintained somewhat higher than the EVT of the asphalt The actual maintenance temperature of the kettle will vary according to outdoor temperature, length of hot pipe, asphalt usage rate, pump flow rate, and type of receiving vessels on the roof Table 1 shows the EVT and other thermal properties for four types of asphalt The flashpoint (FP) is the temperature at which the asphalt may burst into flame The maximum heating temperature is 25°F less than the FP and should never be exceeded The type of asphalt used in an application is determined by, among other things, the slope of the roof being built

Table 1 Thermal Properties of Various Types of Asphalt				
Type Number	Kind of Asphalt	Maximum Heating Temperature (°F)	Flash-point Temperature (°F)	EVT ±25 °F
Type I	Dead Level	475	525	375
Type II	Flat	500	550	400
Type III	Steep	525	575	425
Type IV	Special	525	575	425

HEALTH EFFECTS/OCCUPATIONAL EXPOSURE CRITERIA

There are three primary sources used in the United States for environmental evaluation criteria NIOSH Recommended Exposure Limits (RELs), the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and the U S Department of Labor OSHA Permissible Exposure Limits (PELs) OSHA has specific PELs regulating the construction industry [21] The OSHA PELs are the only legally enforceable exposure criteria among those listed, and during their development, OSHA must consider the feasibility of controlling exposures in addition to the related health effects In contrast, NIOSH RELs are based primarily on concerns relating to health effects The ACGIH TLVs refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be exposed, day after day, without adverse health effects The ACGIH is a private professional society and states that the TLVs are only guidelines

In a 1988 rule on air contaminants, OSHA proposed a PEL of 5 mg/m^3 as an 8-hr time-weighted average (TWA) for asphalt fumes exposure in general industry This proposal was based on a preliminary finding that asphalt fumes should be considered a potential carcinogen [22] In 1989, OSHA announced that it would delay a final decision on the 1988 proposal because of complex and conflicting issues submitted to the record [23] In 1992, OSHA published another proposed rule for asphalt fumes that indicated a PEL of 5 mg/m^3 (total particulate) for general industry, construction, maritime, and agriculture [24] Although OSHA invited comments on all of the alternatives, its proposed standard for asphalt fumes would establish a PEL of 5 mg/m^3 (total particulate) based on avoidance of adverse respiratory effects The OSHA docket is closed, and OSHA has not scheduled any further action

In 1977, NIOSH established an REL of 5 0 mg/m^3 (total particulate) measured as a 15-minute ceiling limit for asphalt fumes to protect against irritation of the serous membrane of the conjunctiva and the mucous membrane of the respiratory tract In 1988, NIOSH (in testimony to the Department of Labor) recommended that, based on the OSHA cancer policy,[25] asphalt fumes should be considered a potential occupational carcinogen [26] This recommendation was based on information presented in the Niemeier et al study [27] This NIOSH conclusion is based on the collective evidence found in available health effects and exposure data [28]

The current ACGIH TLV for asphalt fumes is an 8-hr TWA-TLV of 0 5 mg/m^3 as benzene-extractable inhalable particulate (or equivalent method) with an A4 designation, indicating that it is not classifiable as a human carcinogen [29]

Asphalt fumes have been reported to cause irritation of the mucous membranes of the eyes, nose, and respiratory tract [30] While other symptoms such as coughing and headaches were reported recently, there was no statistical association with asphalt fume exposure [31, 32] Results from experimental studies with animals[27, 33 34] indicate that roofing asphalt fume condensates generated in the laboratory and applied dermally cause benign and malignant skin tumors in several strains of mice Differences in chemical composition and physical characteristics have been noted between roofing asphalt fumes collected in the field and those generated in the laboratory [35] However, the significance of these differences in ascribing health effects to humans is unknown Furthermore, no published data exist that examine the carcinogenic potential of field-generated roofing asphalt fumes in animals Since the health risks from asphalt exposure are not yet fully defined, NIOSH, labor, and industry are working together to better characterize these risks while continuing their effort to reduce worker exposures to asphalt fumes

In the roofing industry, exposure to asphalt fumes and other related exposures is well documented and studies still continue Several studies have identified increased polycyclic aromatic compounds (PACs) exposure in kettle operators versus other categories of roofers [27] Due to the nature of the kettle operator's job, this appears to be an obvious conclusion, however, few controls have been utilized to minimize these exposures

ENGINEERING CONTROLS

The engineering control evaluated during this field study was the Cleasby afterburner system equipped with a loading door In the Cleasby afterburner system, the regular kettle lid is replaced with a lid fitted a hood and ducting leading to the afterburner system As the asphalt fumes emit from the surface of the asphalt in the kettle, they are drawn by a fan in the afterburner unit through the ducting to propane burners where the asphalt fumes are combusted in the burners The afterburner unit is separate from the kettle on it own small trailer which can be pulled around to different locations near the kettle

STUDY BACKGROUND

A survey was conducted July 16 through 25, 2002, at Glenwood Elementary School in San Rafael, California with Henris Roofing A built-up roof (BUR) was being applied to an existing school building where the old roof had been removed by another crew of workers Other existing engineering controls for this industry are being evaluated in other surveys A final report will summarize each of the engineering controls evaluated in the surveys

SITE DESCRIPTION AND WORK ACTIVITY

Glenwood Elementary School is a large, multiple-wing school that was undergoing a complete renovation All the old roofs had been torn-off and the under board had been replaced or repaired The roof being applied consisted of one layer of Fresco board installation/mineral fiber board, 3-plies of black fiber glass felt paper, and a mineral surface fiber glass cap sheet Shown in Table 2 is the amount of asphalt used each day of the survey

Table 2 Amount of Asphalt Used Each Day Glenwood Elementary School

Date	Amount of Asphalt Used (pounds)
7/16/2002	2850
7/17/2002	1800
7/18/2002	1050
7/19/2002	1200
7/22/2002	2475
7/23/2002	3375
7/24/2002	1350
7/25/2002	1500

The roofers began work at 7 00 a m each day At that time, the kettle operator loaded asphalt into a 650 gallon kettle manufactured by Cleasby and equipped with a separate afterburner system and lit the propane burners to bring the asphalt up to the correct temperature The kettle was located at ground level in the construction area where the new roof was being installed During the eight days that the survey was conducted, the roofers worked on six different wings installing BUR

EVALUATION METHODS

In order to develop useful and practical recommendations, the ability of the engineering control measure to reduce worker exposure to air contaminants must be documented and evaluated Where practical, this was accomplished by evaluating workers' exposure to asphalt fume particulate and PACs both with and without the afterburner operating and the safety loading kettle lid open and closed Personal breathing zone and area air samples were collected and analyzed for total particulate (TP) and benzene soluble fraction (BSF) of the total particulate using NIOSH Manual of Analytical Methods (NMAM) Method 5042, NMAM Method 5800 was used to analyze the samples for PACs [36] The temperature of the hot asphalt was recorded periodically with an electronic thermocouple and compared to the temperature gauge permanently mounted on the kettle

Air Sampling

The personal breathing zone and area air sampling consisted of two sampling trains per worker or area One sampling train was used to collect TP and BSF, and the other train was used to collect total PACs Both sampling trains' pumps were calibrated to an air flow rate of 2 liters per minute (LPM) Personal breathing zone air samples were collected on the kettle operator and three roof level workers Area air samples were collected at each of the four corners around the kettle The area air samplers were placed in tripods, and the sampling media were positioned to breathing zone height (approximately 60 inches above the ground)

Kettle Temperature

The kettle was equipped with a permanently mounted temperature gauge This gauge reading is used by the kettle operator to monitor and maintain hot asphalt above the EVT The mounted gauge calibration was checked against a Tegam Model 821 microprocessor thermometer using a K-type thermocouple

Summarized in Table 3 for the eight days of sampling at Glenwood Elementary School are the mean kettle temperature measurements along with the mean kettle gauge temperature measurements

Table 3 Summary of Kettle Temperature Data Glenwood Elementary School					
Date	Number of Measurements	Mean Kettle Temperature (°F)	Minimum Kettle Temperature (°F)	Maximum Kettle Temperature (°F)	Mean Gauge Kettle Temperature (°F)
7/16/2002	5	536	528	544	527
7/17/2002	5	527	485	541	506
7/18/2002	5	540	526	547	525
7/19/2002	5	522	515	525	510
7/22/2002	6	521	512	529	515
7/23/2002	4	542	527	560	518
7/24/2002	4	541	539	544	491
7/25/2002	3	519	515	523	512

RESULTS

Kettle Operator Personal Breathing Zone Sample Results

Personal breathing zone air samples collected on the kettle operator at the elementary school site were analyzed for TP, BSF, and total PAC Samples were collected for eight days During the eight days of sampling, the afterburner was on for four days and off for four days The kettle lid was opened when asphalt was added, the loading door was not used The kettle lid was closed the rest of the time The kettle operator also worked on the roof part of the time each day The sample results for the kettle operator are shown in Table 4 and summarized in Table 5

Table 4 Kettle Operators' Exposure Concentrations Glenwood Elementary School								
Sample Date	Worker ID Number	Sample Time (min)	TP Conc (mg/m^3)	BSF Conc (mg/m^3)	370 PAC Conc (μg/m^3)	400 PAC Conc (μg/m^3)	Total PAC Conc (μg/m^3)	Afterburner System Status
7/16/2002	OP-03	457	1 42	1 00	236	39	275	on
7/17/2002	OP-03	404	0 49	0 37	92	14	107	on
7/18/2002	OP-03	430	3 85	3 44	584	96	679	off
7/19/2002	OP-03	348	1 77	1 47	203	34	237	off
7/22/2002	OP-03	419	3 31	1 25	146	52	198	on
7/23/2002	OP-03	492	1 53	0 70	99	21	120	on
7/24/2002	OP-03	465	2 59	1 90	170	45	215	off
7/25/2002	OP-03	438	0 50	0 36	82	14	96	off

For all tables

TP = total particulate
BSF = benzene soluble fraction of TP
PAC = polycyclic aromatic compounds
370 PAC = PAC measured at 370 nm emission wavelength
400 PAC = PAC measured at 400 nm emission wavelength
Total PAC = sum of 370 and 400 nm PAC concentrations
mg/m^3 = milligrams per cubic meter of air
μg/m^3 = micrograms per cubic meter of air
nm = nanometers
na = not available

Table 5 Summary of the Kettle Operator's Exposure Results Glenwood Elementary School			
Exposure Analyte	Mean Concentration		% Difference afterburner on vs afterburner off
	Afterburner on	Afterburner off	
TP (mg/m^3)	1 69	2 18	22 6
BSF (mg/m^3)	0 83	1 79	53 6
Total PAC (μg/m^3)	175	307	43 0

Area Air Sample Results for Samples Collected Around The Kettle

Area air samples were collected at the four corners of the asphalt roofing kettle at breathing zone height Samples were analyzed for TP, BSF, and PAC These results are shown in Table 6 and summarized in Table 7

Table 6. Area Air Sample Concentration Results For Samples Collected Around the Kettle Glenwood Elementary School

Sample Date	Sample Location Around Kettle	Sample Time (min)	TP Conc (mg/m^3)	BSF Conc (mg/m^3)	370 PAC Conc ($\mu g/m^3$)	400 PAC Conc ($\mu g/m^3$)	Total PAC Conc ($\mu g/m^3$)	Afterburner System Status
7/16/2002	NE corner	447	0 21	0 13	8 3	0 5	8 8	on
7/16/2002	NW corner	447	0 37	0 24	49	5 5	55	on
7/16/2002	SE corner	447	0 33	0 10	34	4 3	38	on
7/16/2002	SW corner	447	0 25	0 09	21	2 5	24	on
7/17/2002	NE corner	416	0 17	0 12	47	7 6	54	on
7/17/2002	NW corner	416	0 21	0 12	33	4 5	38	on
7/17/2002	SE corner	416	0 24	0 17	38	5 2	43	on
7/17/2002	SW corner	416	0 22	0 20	69	12	81	on
7/18/2002	NE corner	446	0 19	0 05	9 2	6	10	off
7/18/2002	NW corner	446	7 59	3 48	1372	224	1596	off
7/18/2002	SE corner	446	0 24	0 06	7 6	3	8 0	off
7/18/2002	SW corner	446	0 05	0 03	0 9	0 0	0 9	off
7/19/2002	NE corner	366	0 18	0 20	6 0	0 0	6 0	off
7/19/2002	NW corner	366	2 95	2 92	621	94	715	off
7/19/2002	SE corner	366	0 31	0 01	44	6 1	50	off
7/19/2002	SW corner	366	0 15	0 01	2 5	0 0	2 6	off
7/22/2002	NE corner	436	2 24	0 41	76	15	91	on
7/22/2002	NW corner	436	2 22	0 71	108	22	130	on
7/22/2002	SE corner	436	1 62	0 94	131	33	164	on
7/22/2002	SW corner	436	2 14	0 29	57	11	68	on
7/23/2002	NE corner	496	0 45	0 17	4 5	0 8	5 3	on
7/23/2002	NW corner	496	0 93	0 57	117	22	139	on

Table 6 Area Air Sample Concentration Results For Samples Collected Around the Kettle Glenwood Elementary School								
Sample Date	Sample Location Around Kettle	Sample Time (min)	TP Conc (mg/m^3)	BSF Conc (mg/m^3)	370 PAC Conc (μg/m^3)	400 PAC Conc (μg/m^3)	Total PAC Conc (μg/m^3)	Afterburner System Status
7/23/2002	SE corner	496	0 42	0 13	26	4 2	30	on
7/23/2002	SW corner	496	0 34	0 03	4 5	8 8	13	on
7/24/2002	NE corner	486	0 83	0 82	59	10	69	off
7/24/2002	NW corner	486	2 18	2 15	135	31	166	off
7/24/2002	SE corner	486	0 12	0 10	15	2 5	18	off
7/24/2002	SW corner	486	0 96	0 68	145	27	172	off
7/25/2002	NE corner	440	0 26	0 22	21	3 8	25	off
7/25/2002	NW corner	440	1 10	1 10	88	25	113	off
7/25/2002	SE corner	440	1 21	1 30	437	76	514	off
7/25/2002	SW corner	440	0 09	0 05	13	2 3	15	off

Table 7 Summary Results for Area Air Samples Collected Around the Kettle Glenwood Elementary School			
	Mean Concentration		% Difference afterburner on vs afterburner off
Exposure Analyte	Afterburner on	Afterburner off	
TP (mg/m^3)	0 77	1 15	32 9
BSF (mg/m^3)	0 28	0 82	66 3
Total PAC (μg/m^3)	61 3	218	71 8

Roof Level Worker Personal Breathing Zone Sample Results

Personal breathing zone air samples were collected on the roof level workers Two workers, one mopping and one laying board, felt, and cap sheet, were sampled for TP, BSF, and total PAC for eight days These sample results are shown in Table 8 and summarized in Table 9

Table 8 Roof-Level Workers' Exposure Concentrations Glenwood Elementary School								
Sample Date	Worker ID Number	Sample Time (min.)	TP Conc (mg/m^3)	BSF Conc (mg/m^3)	370 PAC Conc ($\mu g/m^3$)	400 PAC Conc ($\mu g/m^3$)	Total PAC Conc ($\mu g/m^3$)	Afterburner System Status
7/16/2002	OP-01	374	0.74	0.64	164	26	190	on
7/16/2002	OP-02	376	0.90	0.77	201	32	233	on
7/17/2002	OP-01	326	0.59	0.49	103	17	120	on
7/17/2002	OP-02	327	0.81	0.75	272	35	306	on
7/18/2002	OP-01	212	1.33	0.95	20	0.0	20	off
7/18/2002	OP-02	205	2.09	1.82	392	63	455	off
7/19/2002	OP-01	152	3.01	1.75	436	71	507	off
7/19/2002	OP-02	145	0.65	0.46	160	23	183	off
7/22/2002	OP-01	243	0.32	0.27	13	2	15	on
7/22/2002	OP-02	243	0.48	0.37	95	17	112	on
7/23/2002	OP-01	180	1.01	0.66	136	23	159	on
7/23/2002	OP-02	176	2.18	1.87	230	50	280	on
7/24/2002	OP-01	147	1.14	1.07	188	33	221	off
7/24/2002	OP-02	141	1.20	1.12	239	44	284	off
7/25/2002	OP-04	235	0.67	0.48	82	14	96	off
7/25/2002	OP-05	270	0.37	0.35	68	11	79	off

Table 9 Summary of the Roof level Workers' Exposure Results Glenwood Elementary School			
Exposure Analyte	Mean Concentration		% Difference afterburner on vs afterburner off
	Afterburner on	Afterburner off	
TP (mg/m^3)	0.88	1.31	32.7
BSF (mg/m^3)	0.73	1.00	27.2
Total PAC ($\mu g/m^3$)	177	231	23.3

Statistical Analysis of the Effectiveness of Using an Afterburner System to Reduce Worker and Area Air Exposures to Asphalt Fumes

Statistical analyses were conducted on the air sampling data to determine the effectiveness of reducing worker exposure to asphalt fumes by using an afterburner system. A summary of these analyses are shown in Table 10. Comparisons were made between air sample results for TP, BSF, and total PAC with the afterburner on and the kettle lid closed to when the afterburner was off and the kettle lid was closed. Comparisons were made for the following groups: the kettle operator, the four area samples collected around the asphalt kettle, and the roof-level workers. Included in Table 10 are percent differences in exposure to the mean TP, BSF, and total PAC concentrations, p-values, t-values, and critical t-values at 95% confidence.

Using t distribution, reductions in exposures were tested to determine if they were statistically significant at 95% confidence. None of the reductions measured for the kettle operator, area air samples collected around the kettle or roof-level workers were found to be statistically significant at 95% confidence.

Table 10 Summary of Statistical Analyses
Glenwood Elementary School

Comparison Group/Analyte	Afterburner Condition	Percent Difference in Exposure	p-value	t-value	Critical t at 95% confidence
Kettle Operator/TP	on vs off	22.6	0.31	0.54	1.94
Kettle Operator/BSF	on vs off	53.6	0.10	1.44	1.94
Kettle Operator/Total PAC	on vs off	43.0	0.18	0.99	1.94
Area Samples Around Kettle/TP	on vs off	32.9	0.23	0.73	1.70
Area Samples Around Kettle/BSF	on vs off	**66.3**	0.03	**1.91**	1.70
Area Samples Around Kettle/Total PAC	on vs off	71.8	0.07	1.48	1.70
Roof-Level Workers/TP	on vs off	32.7	0.13	1.16	1.76
Roof-Level Workers/BSF	on vs off	27.2	0.16	1.02	1.76
Roof-Level Workers/Total PAC	on vs off	23.3	0.23	0.76	1.76

Bold = statistical significance at 95% confidence

Comparison of Results after Adjusting Exposure Concentrations to Normal Temperature and Pressure

Normal temperature and pressure (NTP) are 77°F (25°C) and 29 92 in Hg (760 mmHg) The ambient air temperature and pressure measurement for the eight days of sampling are shown in Table 11

Table 11 Mean Ambient Air Temperature and Pressure Measurements Glenwood Elementary School

Date	Number of Measurements	Mean Ambient Air Temperature (°F)	Mean Barometric Pressure (in Hg)
7/16/2002	8	72 0	29 96
7/17/2002	8	71 9	30 00
7/18/2002	9	63 3	30 00
7/19/2002	7	66 4	29 92
7/22/2002	10	67 5	29 96
7/23/2002	11	66 1	30 04
7/24/2002	10	67 1	30 08
7/25/2002	8	64 8	30 08

Using the mean temperature and pressure measurements for the day the sample was collected, the TP, BSF, and PAC exposure results were adjusted to NTP These data are shown in Table 12 for the kettle operators, Table 14 for the area air samples collected around the kettle, and Table 16 for the roof level workers By adjusting to NTP, data from different sites can be more readily compared

Table 12 Kettle Operator NTP Exposure Results Glenwood Elementary School					
Sample Date	Worker ID Number	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc ($\mu g/m^3$)	Afterburner System Status
7/16/2002	OP-03	1 40	0 99	272	on
7/17/2002	OP-03	0 48	0 36	105	on
7/18/2002	OP-03	3 74	3 34	660	off
7/19/2002	OP-03	1 74	1 44	232	off
7/22/2002	OP-03	3 24	1 23	194	on
7/23/2002	OP-03	1 50	0 69	117	on
7/24/2002	OP-03	2 53	1 86	210	off
7/25/2002	OP-03	0 48	0 35	93	off

Table 13 Summary of the Kettle Operator NTP Exposure Results Glenwood Elementary			
	Mean Concentration		% Difference afterburner on vs afterburner off
Exposure Analyte	Afterburner on	Afterburner off	
NTP TP (mg/m^3)	1 66	2 12	22 0
NTP BSF (mg/m^3)	0 82	1 75	53 2
NTP Total PAC ($\mu g/m^3$)	172	299	42 4

Table 14 Area Air Sample NTP Results Collected Around the Kettle Glenwood Elementary School						
Sample Date	Sample Location Around Kettle	Sample Time (min)	NTP TP Conc (mg/m³)	NTP BSF Conc (mg/m³)	NTP Total PAC Conc (μg/m³)	Afterburner System Status
7/16/2002	NE corner	447	0 21	0 13	8 7	on
7/16/2002	NW corner	447	0 37	0 24	54 0	on
7/16/2002	SE corner	447	0 32	0 10	37 5	on
7/16/2002	SW corner	447	0 25	0 09	23 3	on
7/17/2002	NE corner	416	0 17	0 12	53 5	on
7/17/2002	NW corner	416	0 20	0 12	37 1	on
7/17/2002	SE corner	416	0 24	0 17	42 4	on
7/17/2002	SW corner	416	0 22	0 20	79 9	on
7/18/2002	NE corner	446	0 18	0 05	9 5	off
7/18/2002	NW corner	446	7 38	3 38	1551	off
7/18/2002	SE corner	446	0 24	0 06	7 7	off
7/18/2002	SW corner	446	0 05	0 03	0 8	off
7/19/2002	NE corner	366	0 17	0 20	5 9	off
7/19/2002	NW corner	366	2 89	2 86	701	off
7/19/2002	SE corner	366	0 30	0 01	49 2	off
7/19/2002	SW corner	366	0 14	0 01	2 5	off
7/22/2002	NE corner	436	2 20	0 40	89 2	on
7/22/2002	NW corner	436	2 18	0 70	127	on
7/22/2002	SE corner	436	1 59	0 92	161	on
7/22/2002	SW corner	436	2 10	0 28	66 7	on
7/23/2202	NE corner	496	0 44	0 17	5 1	on
7/23/2202	NW corner	496	0 90	0 56	135	on
7/23/2202	SE corner	496	0 41	0 13	29 6	on
7/23/2202	SW corner	496	0 33	0 03	13 0	on

Table 14 Area Air Sample NTP Results Collected Around the Kettle Glenwood Elementary School						
Sample Date	Sample Location Around Kettle	Sample Time (min)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc ($\mu g/m^3$)	Afterburner System Status
7/24/2002	NE corner	486	0 81	0 80	67 6	off
7/24/2002	NW corner	486	2 13	2 10	162	off
7/24/2002	SE corner	486	0 12	0 10	17 5	off
7/24/2002	SW corner	486	0 94	0 67	168	off
7/25/2002	NE corner	440	0 26	0 21	24 5	off
7/25/2002	NW corner	440	1 07	1 06	110	off
7/25/2002	SE corner	440	1 18	1 26	499	off
7/25/2002	SW corner	440	0 09	0 05	14 4	off

Table 15 Summary of the Area Air Sample NTP Results Collected Around the Kettle Glenwood Elementary School			
	Mean Concentration		% Difference afterburner on vs afterburner off
Exposure Analyte	Afterburner on	Afterburner Off	
NTP TP (mg/m^3)	0 76	1 12	32 4
NTP BSF (mg/m^3)	0 27	0 80	66 1
NTP Total PAC ($\mu g/m^3$)	60 2	212	71 6

Table 16 Roof Level Workers' NTP Exposure Results Glenwood Elementary School						
Sample Date	Worker ID Number	Sample Time (min)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc (μg/m^3)	Afterburner System Status
7/16/2002	OP-01	374	0 74	0 63	188	on
7/16/2002	OP-02	376	0 89	0 76	230	on
7/17/2002	OP-01	326	0 59	0 49	118	on
7/17/2002	OP-02	327	0 80	0 74	303	on
7/18/2002	OP-01	212	1 29	0 92	19 6	off
7/18/2002	OP-02	205	2 03	1 77	442	off
7/19/2002	OP-01	152	2 95	1 72	497	off
7/19/2002	OP-02	145	0 63	0 45	179	off
7/22/2002	OP-01	243	0 32	0 27	14 5	on
7/22/2002	OP-02	243	0 47	0 36	110	on
7/23/2002	OP-01	180	0 98	0 65	155	on
7/23/2002	OP-02	176	2 13	1 83	274	on
7/24/2002	OP-01	147	1 11	1 04	216	off
7/24/2002	OP-02	141	1 17	1 10	277	off
7/25/2002	OP-04	235	0 65	0 46	93 2	off
7/25/2002	OP-05	270	0 36	0 34	77 0	off

Table 17 Summary of the Roof Level Workers' NTP Exposure Results Glenwood Elementary School			
	Mean Concentration		% Reduction afterburner on vs afterburner off
Exposure Analyte	Afterburner on	Afterburner off	
NTP TP (mg/m^3)	0 86	1 28	32 3
NTP BSF (mg/m^3)	0 72	0 98	26 7
NTP Total PAC ($\mu g/m^3$)	174	225	22 7

Statistical Analysis of the Effectiveness of Using an Afterburner System to Reduce Worker and Area Air Exposures to Asphalt Fumes Adjusted to NTP

Statistical analyses were conducted on the NTP air sampling data to determine the effectiveness of reducing worker exposure to asphalt fumes by using an afterburner system with a safety loading door A summary of these analyses is shown in Table 18 Comparisons were made between air sample results for NTP TP, BSF, and total PAC while the afterburners were on and the kettle lid was closed and when the afterburner was off and the kettle lid was closed Comparisons were made for the following groups the kettle operator, the four area air samples collected around the kettle, and the roof-level workers Included in Table 18 are percent differences in exposure to the mean NTP TP, BSF, and total PAC, p-values, t-values, and critical t-values at 95% confidence

Using t distribution, reductions in exposures were tested to determine if they were statistically significant at 95% confidence None of the reductions measured for the kettle operator, area air samples collected around the kettle or roof-level workers were found to be statistically significant at 95% confidence Adjusting the exposure results to NTP did not alter the significance of the reductions

Table 18 Summary of Statistical Analyses of NTP Exposures Glenwood Elementary School					
Comparison Group/Analyte	Afterburner Condition	Percent Difference in Exposure	p-value	t-value	Critical t at 95% confidence
Kettle Operator/NTP TP	on vs off	22 0	0 31	0 52	1 94
Kettle Operator/NTP BSF	on vs off	53 2	0 10	1 44	1 94
Kettle Operator/NTP Total PAC	on vs off	42 4	0 18	0 97	1 94
Area Samples Around Kettle/NTP TP	on vs off	32 4	0 24	0 72	1 70

Table 18 Summary of Statistical Analyses of NTP Exposures Glenwood Elementary School					
Comparison Group/Analyte	Afterburner Condition	Percent Difference in Exposure	p-value	t-value	Critical t at 95% confidence
Area Samples Around Kettle/NTP BSF	on vs off	**66 1**	0 03	**1 90**	1 70
Area Samples Around Kettle/NTP Total PAC	on vs off	71 6	0 08	1 48	1 70
Roof-Level Workers/NTP TP	on vs off	32 3	0 14	1 15	1 76
Roof-Level Workers/NTP BSF	on vs off	26 7	0 17	1 00	1 76
Roof-Level Workers/NTP Total PAC	on vs off	22 7	0 24	0 73	1 76

Bold = statistically significant at 95% confidence

DISCUSSION

Various engineering controls are being investigated to determine their effectiveness at reducing asphalt fume emissions from roofing kettles This report summarizes a survey conducted at a site that used an afterburner system with a safety loading door as the engineering control Both personal and area air samples were collected on this survey Personal samples were collected on the kettle operator and the roof level workers when the afterburner system was in operation and when it was not in operation All samples were analyzed for TP, BSF, and total PAC Personal and area samples were collected for eight days, four days when the afterburner was operating and four days when the afterburner was not operating The results were then compared to determine if there was a reduction in these indices of exposure when the afterburner system was in use

For the kettle operator, the mean concentrations of TP, BSF, and total PAC were reduced by 23%, 54% and 43%, respectively, when the afterburner was on compared to the afterburner off None of these reductions were statistically significant The kettle operator loaded all asphalt into the kettle by opening the kettle lid instead of using the loading door, thus allowing asphalt fume to be emitted from the kettle during this work activity The kettle operator also spent half his day working on the roof, getting a similar asphalt fume exposure as the other roof level works Both of these situations probably increased the kettle operator's exposure to asphalt fumes Results seen in the area air samples collected around the kettle had greater reductions than seen for the kettle operator Reductions of 33%, 66%, and 72% for TP, BSF, and total PAC, respectively, were seen when comparing mean concentrations when the afterburner was on to when the afterburner was off Only the reduction seen in the BSF area air sample result was statistically significant

Personal samples were collected on the roof level workers who were mopping and lugging asphalt Reductions for TP, BSF, and total PAC exposures of 33%, 27%, and 23%, respectively, were measured for the roof level workers when comparing mean concentrations with the afterburner operating to when the afterburner was not operating However, none of these reductions were statistically significant Since the outside air temperature impacts the operating temperature of the kettle, and the kettle temperature affects the amount of asphalt fume emissions, the results were adjusted to normal temperature and pressure This also allows data from different sites that may have significantly different weather conditions to be compared After making this adjustment, there was no change in the significance of the results

These results indicate that using an afterburner system reduced the kettle operator's exposure to asphalt fumes, although none of the reductions measured were statistically significant These results were somewhat lower than those measured for the area samples collected around the kettle

The roof level workers did seem to benefit somewhat from the use of the afterburners on the kettle as their exposures to TP, BSF, and total PAC were all reduced However, these reductions were not statistically significant at 95% confidence

CONCLUSIONS

The use of an afterburner system on the roofing kettle reduced worker exposure to asphalt fumes However, none of the reductions were statistically significant This may be the result of the fact that the kettle operator loaded all the asphalt to the kettle by opening the kettle lid instead of using the loading door Further study is needed to determine if afterburner systems could be effective at reducing asphalt fume emissions

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