SURVEY REPORT:

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

AT

Nicholes Elementary School
San Antonio, Texas

REPORT WRITTEN BY
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FACILITY SURVEYED	Nicholes Elementary School Braun Rd San Antonio, Texas
SIC CODE	1761
SURVEY DATES	November 26 through December 1, 2001
SURVEY CONDUCTED BY	David A Marlow
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SUMMARY

From November 26 through December 1, 2001, a field survey was conducted at a new construction site where a built up asphalt roof was being installed at Nicholes Elementary School in San Antonio, Texas 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 afterburners on and kettle lid closed and the afterburners off and kettle lid closed Air samples were collected on the kettle operator, two roof level workers, and area air samples collected around the four corners of the kettle

Four days of sampling were conducted at Nicholes Elementary School Due to a laboratory error, two days of sampling were lost The kettle operator's exposures to TP, BSF, and total PAC were all increased 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 Increases in exposures for the kettle operator of 147%, 397%, and 367% for TP, BSF, and total PAC were measured The comparison of the results for the area air samples collected around the kettle showed a reduction of 41% for the TP exposures and an increase of 81% and 95% for BSF and total PAC For the roof level workers, exposures to TP, BSF, and total PAC were reduced 48%, 46%, and 57%, respectively None of the reductions measured were statistically significant ($p \leq 0$ 05) Using the afterburner system with the kettle lid closed did not appear to provide protection from asphalt fume exposure, particularly for the kettle operator

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 In this project, existing engineering controls for asphalt fume exposures to roofing kettle operators are evaluated and, if necessary, redesigned to reduce operator exposures 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]

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, make 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 "post office" type 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 is 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 survey was the Reeves afterburner system equipped with the safety loader In the Reeves afterburner system, the regular kettle lid is replaced with a lid fitted with a hood containing propane burners in the fume stacks and a loading chamber for adding asphalt to the kettle As asphalt fumes are emitted from the surface of the asphalt in the kettle and rise up into the stacks, they are combusted in the burners The safety loader provides a way to add asphalt to the kettle without risk of being splashed with hot asphalt The safety loader consists of a chamber with a door where chunks of asphalt are placed The bottom of the chamber has a hinged door attached to a lever which, when pulled, opens and allows the asphalt to fall into the kettle

STUDY BACKGROUND

A survey was conducted November 26 through December 1, 2001 at Nicholes Elementary School in San Antonio, Texas with the Beldon Roofing Company Worker exposures to asphalt fumes during the installation of an asphalt built-up roof (BUR) were evaluated with and without an engineering control The engineering control used at this site was a Reeves afterburner system Other existing engineering controls for this industry are also being evaluated A final report will summarize the engineering controls evaluated from all of the surveys

SITE DESCRIPTION AND WORK ACTIVITY

Nicholes Elementary School is a large multiple wing school that was under construction when the survey was conducted During this time, the roof over one of the wings was being installed The roof being applied consisted of one layer of polyisocyanurate installation board, a layer of Perlite board, 2-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

Date	Amount of Asphalt Used (pounds)
11/26/2001	2250
11/27/2001	1700
11/30/2001	4700
12/01/2001	3300

The roofers began work at 8 00 a m each day At that time, the kettle operator loaded asphalt into a 650 gallon kettle (manufactured by Reeves) equipped with two afterburners and lit the propane burners to bring the asphalt up to the correct temperature The elementary school consisted of multiple wings The kettle was located at ground level in front of the wing where the BUR was being installed During the four days that the survey was conducted, the roofers worked on one wing installing BUR

EVALUATION METHODS

In order to develop useful and practical recommendations, the ability of an 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 both open and closed In this particular survey, the kettle lid was closed for all measurements Personal breathing zone and area air samples were collected for total particulate (TP), benzene soluble fraction (BSF) of the total particulate, and PACs The samples were analyzed for BSF using NIOSH Manual of Analytical Methods (NMAM) Method 5042, NMAM Method 5800 was used to analyze 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

For personal breathing zone and area air sampling, two sampling trains were used per worker or area One sampling train was used to collect TP and BSF samples, and the other train was used to collect total PAC samples Both sampling trains' sampling pumps were calibrated to an air sampling 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 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 Table 3 contains the kettle temperature data for the four days of sampling at Nicholes Elementary School The mean kettle temperature measurements are shown along with the mean kettle gauge temperature measurements

Table 3. Summary of Kettle Temperature Data Nicholes Elementary School					
Date	Number of Measurements	Mean Kettle Temperature (°F)	Minimum Kettle Temperature (°F)	Maximum Kettle Temperature (°F)	Mean Gauge Kettle Temperature (°F)
11/26/2001	3	561	526	590	593
11/27/2001	0	----	----	----	552
11/30/2001	2	552	544	559	555
12/01/2001	2	530	516	540	534

Statistical Evaluation

Personal breathing zone and area air sample data for TP, BSF, and total PAC were statistically compared with afterburners on and the kettle lid closed to afterburners off and the kettle lid closed using Student's t-test Statistical comparisons were also done for the personal breathing zone and area air sampling data adjusted to normal temperature and pressure (NTP)

RESULTS

Kettle Operator Sampling 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 four days During the analysis of the samples, the first two days' samples (11/26 and 11/27) were lost Therefore, shown in Table 4 are the sample results for only the third and fourth day of sampling for the kettle operator On the third day of sampling, the afterburner was on and the kettle lid was closed On the fourth day of sampling, the afterburner was off and the kettle lid was closed

Table 4 Kettle Operator's Exposure Concentrations *Nicholes Elementary School*							
Sample Date	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 ($\mu g/m^3$)	Kettle Conditions
11/30/2001	461	0 94	0 60	40 7	8 25	49 0	afterburner on, lid closed
12/01/2001	279	0 39	0 13	7 26	3 63	10 9	afterburner off, lid closed

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
$\mu g/m^3$ = micrograms per cubic meter of air
nm = nanometers
na = not available

Table 5 Summary of the Kettle Operator's Exposure Results Nicholes Elementary School			
Exposure Analyte	Kettle Conditions		% Difference afterburner on/lid closed vs afterburner off/lid closed
	afterburner on/lid closed	afterburner off/lid closed	
TP (mg/m^3)	0 94	0 39	-138
BSF (mg/m^3)	0 60	0 13	-379
Total PAC ($\mu g/m^3$)	49 0	10 9	-350

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 collected and analyzed for TP, BSF, and PAC These results are shown in Table 6

Table 6 Area Air Sample Concentration Results Collected Around the Kettle Nicholes Elementary School								
Sample Date	Sample Location Around Kettle	Sample Time (min)	TP Conc (mg/m³)	BSF Conc (mg/m³)	370 PAC Conc (µg/m³)	400 PAC Conc (µg/m³)	Total PAC Conc (µg/m³)	Kettle Conditions
11/30/2001	NE corner	474	0 11	0 06	33 3	6 87	40 2	afterburner on, lid closed
11/30/2001	NW corner	474	0 24	0 22	76 8	13 8	89 6	afterburner on, lid closed
11/30/2001	SE corner	474	0 02	0 04	130	24 2	154	afterburner on, lid closed
11/30/2001	SW corner	474	0 04	0 02	36 6	7 10	43 7	afterburner on, lid closed
12/01/2001	NE corner	279	0 18	0 03	0 66	2 82	3 49	afterburner off, lid closed
12/01/2001	NW corner	279	0 16	0 03	0 62	2 82	3 44	afterburner off, lid closed
12/01/2001	SE corner	279	0 18	0 05	14 6	7 40	22 0	afterburner off, lid closed
12/01/2001	SW corner	279	0 20	0 09	0 65	2 92	3 57	afterburner off, lid closed

Table 7 Summary of the Area Air Sample Results Collected Around the Kettle Nicholes Elementary School			
	Mean Concentration		% Difference afterburner on/lid closed vs afterburner off/lid closed
Exposure Analyte	afterburner on/lid closed	afterburner off/lid closed	
TP (mg/m³)	0 10	0 18	43 4
BSF (mg/m³)	0 08	0 05	-73 7
Total PAC (µg/m³)	81 9	8 13	-907

Roof Level Worker Personal Breathing Zone Sample Results

Personal breathing zone air samples were collected on the roof level workers at the elementary school Two workers, one who was mopping and one who was lugging asphalt, were sampled for TP, BSF, and total PAC for four days These sample results are shown in Table 8 and summarized in Table 9

Table 8 Roof-Level Workers Exposure Concentrations Nicholes Elementary School								
Sample Date	Worker ID Number	Sample Time (min.)	TP Conc (mg/m³)	BSF Conc (mg/m³)	370 PAC Conc (μg/m³)	400 PAC Conc (μg/m³)	Total PAC Conc (μg/m³)	Kettle Conditions
11/30/2001	NP-01	392	3.45	2.30	45.0	9.93	55.0	afterburner on, lid
11/30/2001	NP-02	351	0.86	0.83	393	75.6	468	afterburner on, lid
12/01/2001	NP-05	192	1.45	0.04	207	36.7	244	afterburner off, lid
12/01/2001	NP-07	193	7.24	5.95	857	161	1018	afterburner off, lid

Table 9 Summary of the Roof level Workers Exposure Results Nicholes Elementary School			
	Mean Concentration		% Difference afterburner on/lid closed vs afterburner off/lid closed
Exposure Analyte	afterburner on/lid closed	afterburner off/lid closed	
TP (mg/m³)	2.15	4.34	50.4
BSF (mg/m³)	1.57	2.99	47.7
Total PAC (μg/m³)	262	631	58.5

Statistical Analysis of the Effectiveness of Using an Afterburner System to Control 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 with a safety loading door. A summary of these analyses is 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 air 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 the roof-level workers were found to be statistically significant at 95% confidence.

Table 10 Summary of Statistical Analyses of the Effectiveness of An Afterburner System Reduce Exposures to Asphalt Fumes					
Comparison Group/Analyte	Afterburner/Kettle lid Condition	Percent Difference in Exposure	p-value	t-value	Critical t at 95% confidence
Kettle Operator/TP	on/closed vs off/closed	-138	----	----	----
Kettle Operator/BSF	on/closed vs off/closed	-379	----	----	----
Kettle Operator/Total PAC	on/closed vs off/closed	-350	----	----	----
Area Samples Around Kettle/TP	on/closed vs off/closed	43 4	0 0809	1 5950	1 9431
Area Samples Around Kettle/BSF	on/closed vs off/closed	-73 7	0 2383	-0 7589	1 9431
Area Samples Around Kettle/Total PAC	on/closed vs off/closed	-907	0 0170	-2 7351	1 9431
Roof-Level Workers/TP	on/closed vs off/closed	50 4	0 2807	0 6901	2 9200
Roof-Level Workers/BSF	on/closed vs off/closed	47 7	0 3425	0 4693	2 9200
Roof-Level Workers/Total PAC	on/closed vs off/closed	58 5	0 2444	0 8413	2 9200

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 measurements for the four days of sampling are shown in Table 11

Table 11 Mean Ambient Air Temperature and Pressure Measurements Nicholes Elementary School			
Date	Number of Measurements	Mean Ambient Air Temperature (°F)	Mean Barometric Pressure (in Hg)
11/26/2001	11	73 3	28 78
11/27/2001	4	57 3	28 86
11/30/2001	9	59 0	29 01
12/01/2001	8	57 2	29 13

Using the temperature and pressure measurements for the time of day the sample was collected, the TP, BSF, and PAC exposure results were adjusted to NTP These data are shown in Table 12 and summarized in Table 13 for the kettle operator, Table 14 and summarized in Table 15 for the area air samples collected around the kettle, and Table 16 and summarized in Table 17 for the roof level workers By adjusting to NTP, data from different sites can be more readily compared

Table 12 Kettle Operator's NTP Exposure Concentrations Nicholes Elementary School

Sample Date	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc (μg/m^3)	Kettle Conditions
11/30/2001	0 93	0 60	38 7	afterburner on/lid closed
12/01/2001	0 39	0 12	8 28	afterburner off/lid closed

Table 13. Summary of the Kettle Operator's NTP Exposure Results Nicholes Elementary School

Exposure Analyte	*Afterburner/Lid Condition*		% Difference
	afterburner on/ lid closed	afterburner off/ lid closed	afterburner on/lid closed vs afterburner off/lid closed
NTP TP (mg/m^3)	0 74	0 30	-147
NTP BSF (mg/m^3)	0 48	0 10	-397
NTP Total PAC (μg/m^3)	38 7	8 28	-367

Table 14 Area Air Sample Concentration Results Collected Around the Kettle Nicholes 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 (μg/m^3)	Kettle Conditions
11/30/2001	NE corner	474	0 11	0 06	31 7	afterburner on, lid closed
11/30/2001	NW corner	474	0 24	0 21	70 8	afterburner on, lid closed
11/30/2001	SE corner	474	0 02	0 04	122	afterburner on, lid closed
11/30/2001	SW corner	474	0 04	0 02	34 5	afterburner on, lid closed
12/01/2001	NE corner	279	0 18	0 03	2 65	afterburner off, lid closed

Table 14 Area Air Sample Concentration Results Collected Around the Kettle Nicholes 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 (μg/m^3)	Kettle Conditions
12/01/2001	NW corner	279	0 16	0 03	2 62	afterburner off, lid closed
12/01/2001	SE corner	279	0 18	0 05	16 7	afterburner off, lid closed
12/01/2001	SW corner	279	0 19	0 09	2 71	afterburner off, lid closed

Table 15 Summary of NTP Area Air Sample Results Collected Around the Kettle Nicholes Elementary School			
	Mean Concentration		% *Difference* afterburner on/lid closed vs *afterburner off/lid closed*
Exposure Analyte	afterburner on/ lid closed	afterburner off/ lid closed	
NTP TP (mg/m^3)	0 08	0 14	41 2
NTP BSF (mg/m^3)	0 07	0 04	-80 6
NTP Total PAC (μg/m^3)	64 7	6 18	-947

Table 16 Roof-Level Workers' Exposure Concentrations Nicholes 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)	Kettle Conditions
11/30/2001	NP-01	392	3 44	2 29	43 4	afterburner on/lid closed
11/30/2001	NP-02	351	0 86	0 83	370	afterburner on/lid closed
12/01/2001	NP-05	192	1 43	0 04	185	afterburner off/lid closed
12/01/2001	NP-07	193	7 16	5 88	774	afterburner off/lid closed

Table 17 Summary of the Roof level Workers Exposure Results Nicholes Elementary School			
Exposure Analyte	Mean Concentration		% Difference afterburner on/lid closed vs afterburner off/lid closed
	afterburner on/ lid closed	afterburner off/ lid closed	
NTP TP (mg/m^3)	1 70	3 30	48 4
NTP BSF (mg/m^3)	1 24	2 28	45 6
NTP Total PAC ($\mu g/m^3$)	207	479	56 9

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 afterburners were 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 the 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 the Effectiveness of Using An Afterburner System to Reduce Exposures to Asphalt Fumes					
Comparison Group/Analyte	Afterburner/Kettle Lid Condition	Percent Difference in Exposure	p-value	t-value	Critical t at 95% confidence
Kettle Operator/NTP TP	on/closed vs off/closed	-147	----	----	----
Kettle Operator/NTP BSF	on/closed vs off/closed	-397	----	----	----
Kettle Operator/NTP Total PAC	on/closed vs off/closed	-367	----	----	----
Area Samples Around Kettle/NTP TP	on/closed vs off/closed	41 2	0 0976	1 4571	1 9432
Area Samples Around Kettle/NTP BSF	on/closed vs off/closed	-80 6	0 2269	-0 8008	1 9432
Area Samples Around Kettle/NTP Total PAC	on/closed vs off/closed	-94 7	0 0167	-2 7495	1 9432
Roof-Level Workers/NTP TP	on/closed vs off/closed	48 4	0 2888	0 6591	2 9200
Roof-Level Workers/NTP BSF	on/closed vs off/closed	45 6	0 3490	0 4480	2 9200
Roof-Level Workers/NTP Total PAC	on/closed vs off/closed	56 9	0 2513	0 8107	2 9200

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 taken on the kettle operator and the roof level workers All samples were analyzed for TP, BSF, and total PAC The results were then compared to determine if there was a reduction in these indices when the afterburner system was in use

For the kettle operator, the concentrations of TP, BSF, and total PAC were higher when the afterburner was on compared to when the afterburner was off Similar results were seen in the area air samples collected around the kettle There was a reduction in TP when the afterburner was on, but the concentrations of BSF and total PAC increased The reduction in TP was not statistically significant

Personal samples were collected on the roof level workers who were mopping and lugging asphalt Reductions were calculated for TP, BSF, and total PAC 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 results Reductions were noted for roof level workers and TP in the area air samples collected around the kettle None of the reductions were statistically significant at 95% confidence

These results indicate that using an afterburner system did not reduce the kettle operator's exposure, although some reduction was noted for the roof level workers The kettle operator's measured exposures were actually higher when the afterburner was on This may indicate that the exhaust of the afterburner needs to be redirected so that it does not enter the operator's breathing zone These results are consistent with those for the area samples collected around the kettle These samples also indicated higher levels of BSF and total PAC when the afterburners were on The fact that the kettle lid was closed during all the sampling may have had some impact on the results, since an open kettle lid may be a source of additional asphalt fume exposure

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 Adjusting the data to NTP did not have a significant impact on the results

CONCLUSIONS

In this survey, the use of an afterburner system on a roofing kettle did not cause a significant reduction in exposure to the components of asphalt fumes In fact, the kettle operator's exposures were elevated when the afterburner system was in use Although the roof level workers had reduced concentrations of TP, BSF, and total PAC, these reductions were not statistically significant Further study is needed to determine if afterburner systems could be effective at reducing asphalt fume emissions

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