SURVEY REPORT.

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

at

Jo and George Marti Elementary School
Cleburne Independent Schools
2020 West Kilpatrick St
Cleburne, Texas

REPORT WRITTEN BY
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FACILITIES SURVEYED	Jo and George Marti Elementary School Cleburne Independent Schools 2020 West Kilpatrick St Cleburne, Texas
SIC CODE	1761
SURVEY DATES	February 4, 5, 11, 12, 18, and 19, 2003
SURVEY CONDUCTED BY	David A Marlow
FACILITY REPRESENTATIVE	No facility representative available
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SUMMARY

On February 4, 5, 11, 12, 18, and 19, 2003, a field survey was conducted at a construction site where a built up asphalt roof was being install on Jo and George Marti Elementary School in Cleburne, Texas. The school was a new school under construction. 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 afterburner 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.

Only the kettle operator's exposure to TP was reduced (74%) when the afterburner was on and the kettle lid was closed when compared to when the afterburner was off and the kettle lid was opened. Exposures to BSF and total PAC for the kettle operator increased 17% and 21% for BSF and total PAC when the afterburner was on and the kettle lid was closed when compared to when the afterburner was off and the kettle lid was opened. Reductions of 74%, 84%, and 81% in TP, BSF, and total PAC were measured for the area air samples collected around the kettle 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. For the roof level workers, exposures to TP, BSF, and total PAC increased 275%, 287%, and 142%, respectively, 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. None of the reductions measured were statistically significant ($p \le 0.05$).

Although the results generally did not show a statistically significant reduction in exposure to asphalt fumes, a 74% reduction in TP was measured for the kettle operator. This indicates that the afterburner did have some impact on operator exposure. The kettle operator's measured exposures to BSF and total PAC were higher when the afterburners were on. This may indicate that the exhaust for the afterburner needs to be redirected so that it does not enter the operator's breathing zone. The fact that reductions were seen in the area air sample results when the afterburners were on also indicates that a reduction in the kettle operator's exposures may decrease with the afterburners on if the exhaust was redirected. The increase in exposure for the roof level workers when the afterburners were on would seem to indicate that the afterburner has little effect in reducing their exposures to asphalt fumes.

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

As a result of 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 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 1999, an estimated 50,000 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 [17] Studying ways to reduce exposure to these construction workers addresses the Healthy People 2000 Objectives, the NIOSH National Occupational Research Agenda (NORA), and OSHA priorities [18-20]

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) BUR 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 [21] 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 for regulating the construction industry [22] 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 [23] 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 [24] 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 [25] 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,[26] asphalt fumes should be considered a potential occupational carcinogen [27] This recommendation was based on information presented in the Niemeier et al study [28] This NIOSH conclusion is based on the collective evidence found in available health effects and exposure data [17]

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 to the 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 Reeves afterburner system equipped with the safety loading door In the Reeves afterburner system, the regular kettle lid is replace with a lid fitted with a safety loading door and hood fitted with fume stack containing a propane burner As the asphalt fumes emit from the surface of the asphalt in the kettle and rise up into the stack they are combusted in the burners The safety door loading system provides a way to add asphalt to the kettle without the risk of being splashed with hot asphalt as well as reducing the amount of fumes emitted from the kettle when asphalt is added to it The safety loading door system is a chamber fitted to the kettle lid The chamber has a door wear asphalt is added The bottom of the chamber is a hinged door attached to a level which when pulled opens allowing the asphalt to fall into the kettle

STUDY BACKGROUND

A survey was conducted February 4, 5, 11, 12, 18, and 19, 2003 at a construction site of a new elementary school The roof being installed at the new elementary construction site consisted corrugate metal, GP Toughrock 5/8" Fireguard® Type X board, 2" of insulation, 1 5" Perlite board, Elastophene® 180S cap system (sanded under face and fusible plastic film top) The engineering control used at the elementary school was a Reeves afterburner system Other existing engineering controls for this industry will be evaluated during subsequent surveys A final report will summarize the engineering controls evaluated from all of the surveys

SITE DESCRIPTION AND WORK ACTIVITY

The survey at the Jo and George Marti Elementary school was conducted for six days over a three week period The kettle used at this site had a 650 gallon Reeves afterburner/safety loading door system The afterburners were operated for three days on and three days off Shown in Table 2 is the amount of asphalt used each day

Table 2 Amount of Asphalt Used

Date	Amount of Asphalt Used (pounds)
2/4/2003	3375
2/5/2003	4275
2/11/2003	2250
2/12/2003	3000
2/17/2003	4500
2/18/2003	975

The roofing crew at the elementary school site began work at 8 00 a m each day At that time, the kettle operator fired up a 650 gallon kettle equipped with two afterburners and began loading the kettle with asphalt All asphalt added to the kettle was added by opening the kettle lid, the safety loading door was seldom used The elementary school had multiple wings The kettle was located at ground level in front of the wing where they were installing the roof

EVALUATION METHODS

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), benzene soluble fraction (BSF) of the total particulate, and PACs The NIOSH Manual of Analytical Methods (NMAM) Method 5042 was used in the BSF analysis, while NMAM Method 5800 was used 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 ground level 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 the hot asphalt above the EVT The mounted gauge calibration was checked against a Tegam Model 821 microprocessor thermometer using a K-type thermocouple

The temperature data collected during the six days of sampling at the Jo and George Marti Elementary School are summarized in Table 3 Shown here are the mean kettle temperature measurements along with the mean kettle gauge temperature measurements

Table 3 Summary of Kettle Temperature Data Jo and George Martz Elementary School					
Date	Number of Measurements	Mean Kettle Temperature (°F)	Minimum Kettle Temperature (°F)	Maximum Kettle Temperature (°F)	Mean Gauge Kettle Temperature (°F)
2/4/2003	5	496	434	512	490
2/5/2003	3	510	480	525	496
2/11/2003	3	508	479	527	506
2/12/2003	3	542	535	561	523
2/17/2003	3	536	522	550	512
2/18/2003	3	541	520	565	524

Statistical Evaluation

Personal breathing zone and area air sample data for TP, BSF, and total PAC were statistically compared with afterburners on to the afterburners off Student's t-test was used for this comparison Statistical comparisons were also done for the personal breathing zone and area air sampling data after they had been adjusted to normal temperature and pressure (NTP)

RESULTS

Kettle Operator Personal Breathing Zone Sample Results

Personal breathing zone air samples were collected on the kettle operator at the elementary school site and analyzed for TP, BSF, and total PAC Samples were collected for six days The results kettle operator are listed in Table 4 and summarized Table 5

Table 4 Kettle Operator Exposure Concentrations Jo and George Marti Elementary School							
Sample Date	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 Status
2/4/2003	477	0 34	<0 04	4 64	1 13	5 77	on
2/5/2003	400	0 25	<0 05	4 85	1 19	6 04	off
2/11/2003	501	0 32	0 10	28 4	8 53	37 0	on
2/12/2003	482	0 41	0 12	18 9	5 78	24 7	off
2/17/2003	262	0 40	0 28	29 1	8 93	38 0	on
2/18/2003	554	0 78	0 20	28 0	8 40	36 4	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 Exposure Results Jo and George Marti Elementary School			
	Afterburner Status		% Difference Afterburner on vs Afterburner off
Exposure Analyte	Afterburner on Mean Concentration	Afterburner off Mean Concentration	
TP (mg/m³)	0 35	0 48	26 7
BSF (mg/m³)	0 14	0 12	-16 1
Total PAC (μg/m³)	26 9	22 4	-20 3

Area Air Sample Results For Samples Collected Around The Kettle

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

Table 6 Area Air Sample Concentrations Collected Around the Kettle Jo and George Marti 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)	Afterburner Status
2/4/2003	NE corner	481	0 29	0 15	12 9	3 74	16 6	on
2/4/2003	NW corner	478	0 10	<0 04	2 17	0 43	2 61	on
2/4/2003	SE corner	482	0 10	0 04	10 6	1 86	12 4	on
2/4/2003	SW corner	481	0 26	0 12	15 1	4 21	19 3	on
2/5/2003	NE corner	526	0 46	0 39	51 3	15 0	66 3	off
2/5/2003	NW corner	528	0 75	0 52	61 1	17 7	78 8	off
2/5/2003	SE corner	546	0 48	0 27	19 7	5 72	25 4	off
2/5/2003	SW corner	526	0 09	<0 04	2 03	0 50	2 53	off
2/11/2003	NE corner	514	<0 02	0 04	3 40	0 97	4 37	on
2/11/2003	NW corner	461	0 37	0 26	37 5	10 9	48 4	on
2/11/2003	SE corner	512	0 89	0 79	72 5	20 7	93 2	on

Table 6. Area Air Sample Concentrations Collected Around the Kettle
Jo and George Marti 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)	Afterburner Status
2/11/2003	SW corner	513	0 19	0 11	0 39	2 16	2 56	on
2/12/2003	NE corner	490	0 21	0 16	19 0	5 49	24 5	off
2/12/2003	NW corner	495	2 25	2 25	209	64 8	274	off
2/12/2003	SE corner	494	2 65	2 65	328	99 5	428	off
2/12/2003	SW corner	496	0 21	<0 03	34 6	9 76	44 4	off
2/17/2003	NE corner	554	0 04	<0 04	<0 79	<0 079	<1 58	on
2/17/2003	NW corner	554	na	na	58 3	18 5	76 6	on
2/17/2003	SE corner	554	0 04	<0 04	0 27	0 27	0 54	on
2/17/2003	SW corner	557	1 27	1 27	202	67 4	269	on
2/18/2003	NE corner	555	<0 02	<0 04	1 54	0 51	2 05	off
2/18/2003	NW corner	534	2 52	2 52	244	75 7	320	off
2/18/2003	SE corner	559	0 40	0 27	69 5	23 2	92 6	off
2/18/2003	SW corner	559	9 21	10 1	1123	365	1488	off

Table 7 Summary of the Area Air Samples Collected Around the Kettle
Jo and George Marti Elementary School

Exposure Analyte	Mean Concentration		% Difference Afterburner on vs Afterburner off
	Afterburner on	Afterburner off	
TP (mg/m³)	0 42	1 60	73 8
BSF (mg/m³)	0 26	1 60	83 8
Total PAC (μg/m³)	45 6	237	80 8

Roof Level Worker Personal Breathing Zone Sample Results

Personal breathing zone air samples were collected on the three roof level workers for each of the six days of sampling These sample results are shown in Table 8 and summarized in Table 9

Table 8. Roof-Level Workers Exposure Concentrations
Jo and George Marti 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)	Afterburner Status
2/4/2003	QP-02	337	1 38	0 87	99 7	30 7	130	on
2/4/2003	QP-03	333	2 89	2 13	175	58 8	234	on
2/4/2003	QP-04	330	1 54	0 71	94 8	26 4	121	on
2/5/2003	QP-02	234	0 18	<0 09	11 3	2 83	14 2	off
2/5/2003	QP-05	322	0 38	0 20	42 7	10 7	53 4	off
2/5/2003	QP-06	321	0 14	<0 06	<0 79	<0 32	<1 10	off
2/11/200	QP-07	337	1 64	0 70	112	33 4	146	on
2/11/200	QP-08	339	2 49	0 22	31 5	9 16	40 7	on
2/11/200	QP-09	341	1 39	0 28	34 3	10 0	44 4	on
2/12/200	QP-07	310	1 10	0 63	97 9	29 9	128	off
2/12/200	QP-09	305	0 50	0 20	27 4	8 05	35 5	off
2/12/200	QP-10	305	0 80	0 32	61 6	18 8	80 5	off
2/17/200	QP-07	311	1 23	0 72	28 0	8 83	36 8	on
2/17/200	QP-09	309	0 56	0 30	63 1	18 7	81 8	on
2/17/200	QP-10	3111	1 07	0 60	67 5	20 9	88 4	on
2/18/200	QP-10	332	0 25	<0 06	7 95	2 08	10 0	off
2/18/200	QP-11	200	0 16	<0 10	14 5	4 08	18 6	off
2/18/200	QP-12	391	0 28	0 13	na	na	na	off

Table 9 Summary of the Roof-Level Workers Exposure Results Jo and George Marti Elementary School			
Exposure Analyte	Mean Concentration		% Difference Afterburner on vs Afterburner off
	Afterburner on	Afterburner off	
TP (mg/m^3)	1 58	0 42	-275
BSF (mg/m^3)	0 72	0 19	-285
Total PAC (μg/m^3)	103	42 6	-141

Statistical Analysis of the Effectiveness of Using an Afterburner System with a Safety Loading Door to Reduce Asphalt Fume Exposures

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 with the afterburners operating to when the afterburner were not operating 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 for the mean TP, BSF, and total PAC concentrations, p-values, t-values, and critical t-values at 95% confidence

Table 10 Summary of Statistical Analyses Jo and George Marti Elementary School					
Comparison Group/Analyte	Afterburner Status	Percent Difference in Exposure	p-value	t-value	Critical t At 95% confidence
Kettle Operator/TP	on vs off	26 7	0 23	0 80	2 13
Kettle Operator/BSF	on vs off	-16 1	0 42	-0 22	2 13
Kettle Operator/Total PAC	on vs off	-20 3	0 38	-0 33	2 13
Area Samples Around Kettle/TP	on vs off	73 8	0 07	1 55	1 72
Area Samples Around Kettle/BSF	on vs off	83 8	0 07	1 53	1 72
Area Samples Around Kettle/Total PAC	on vs off	80 8	0 07	1 56	1 72
Roof-Level Workers/TP	on vs off	-275	0 0002	-4 42	1 75
Roof-Level Workers/BSF	on vs off	-285	0 009	-2 66	1 75
Roof-Level Workers/Total PAC	on vs off	-141	0 02	-2 24	1 75

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 six days of sampling are shown in Table 11

Table 11 Mean Ambient Temperature and Pressure Jo and George Marti Elementary School			
Date	Number of Measurements	Mean Ambient Air Temperature (°F)	Mean Barometric Pressure (in Hg)
2/4/2003	9	53 9	29 29
2/5/2003	10	50 9	29 13
2/11/2003	10	65 5	29 17
2/12/2003	9	61 2	29 29
2/17/2003	11	53 1	29 17
2/18/2003	12	59 2	29 05

Using the mean temperature and pressure measurements for that 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 kettles, 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 NTP Exposure Concentrations
Jo and George Marti Elementary School

Sample Date	Sample Time (min)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc ($\mu g/m^3$)	Afterburner Status
2/4/2003	477	0 35	<0 04	5 91	on
2/5/2003	400	0 25	<0 05	6 18	off
2/11/2003	501	0 42	0 12	24 9	on
2/12/2003	482	0 32	0 10	36 8	off
2/17/2003	262	0 41	0 28	38 8	on
2/18/2003	554	0 79	0 20	36 6	off

Table 13. Summary of the Kettle Operators' NTP Exposure Results
Jo and George Marti Elementary School

Exposure Analyte	Mean Concentration		% Difference Afterburner on vs Afterburner off
	Afterburner on	Afterburner off	
NTP TP (mg/m^3)	0 36	0 48	26 4
NTP BSF (mg/m^3)	0 14	0 12	-16 9
NTP Total PAC ($\mu g/m^3$)	27 2	22 5	-20 6

Table 14 Area Air Sample Concentration Results Collected Around the Kettle Jo and George Marti 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)	Afterburner Status
2/4/2003	NE corner	481	0 30	0 16	17 0	on
2/4/2003	NW corner	478	0 11	<0 04	5 91	on
2/4/2003	SE corner	482	0 11	0 04	12 7	on
2/4/2003	SW corner	481	0 26	0 13	19 8	on
2/5/2003	NE corner	526	0 47	0 40	67 8	off
2/5/2003	NW corner	528	0 77	0 53	80 6	off
2/5/2003	SE corner	546	0 49	0 27	26 0	off
2/5/2003	SW corner	526	0 09	<0 04	2 59	off
2/11/2003	NE corner	514	<0 01	0 04	4 35	on
2/11/2003	NW corner	461	0 37	0 26	48 3	on
2/11/2003	SE corner	512	0 89	0 79	92 8	on
2/11/2003	SW corner	513	0 19	0 11	2 55	on
2/12/2003	NE corner	490	0 22	0 16	24 7	off
2/12/2003	NW corner	495	2 27	2 27	276	off
2/12/2003	SE corner	494	2 67	2 67	432	off
2/12/2003	SW corner	496	0 21	<0 03	44 8	off
2/17/2003	NE corner	554	0 04	<0 04	<1 61	on
2/17/2003	NW corner	554	na	na	78 3	on
2/17/2003	SE corner	554	1 29	1 29	275	on
2/17/2003	SW corner	557	0 04	<0 04	0 55	on
2/18/2003	NE corner	555	<0 01	<0 04	2 06	off
2/18/2003	NW corner	534	2 53	2 53	321	off
2/18/2003	SE corner	559	0 40	0 27	93 0	off
2/18/2003	SW corner	559	9 25	10 2	1495	off

Table 15 Summary of NTP Area Air Sample Results Collected Around the Kettle Jo and George Marti Elementary School			
	Mean Concentration		% Difference Afterburner on vs Afterburner off
Exposure Analyte	Afterburner on	Afterburner off	
NTP TP (mg/m^3)	0 43	1 62	73 6
NTP BSF (mg/m^3)	0 26	1 61	83 8
NTP Total PAC (μg/m^3)	46 3	239	80 6

Table 16 Roof-Level Workers' NTP Exposure Concentrations Jo and George Marti 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 Status
2/4/2003	QP-02	337	1 41	0 89	133	on
2/4/2003	QP-03	333	2 96	2 18	239	on
2/4/2003	QP-04	330	1 58	0 73	124	on
2/5/2003	QP-02	234	0 18	<0 09	14 5	off
2/5/2003	QP-05	322	0 39	0 20	54 6	off
2/5/2003	QP-06	321	0 15	<0 06	<1 13	off
2/11/2003	QP-07	337	1 63	0 70	145	on
2/11/2003	QP-08	339	2 49	0 22	40 6	on
2/11/2003	QP-09	341	1 39	0 28	44 2	on
2/12/2003	QP-07	310	1 11	0 63	129	off
2/12/2003	QP-09	305	0 50	0 20	35 8	off
2/12/2003	QP-10	305	0 81	0 32	81 2	off
2/17/2003	QP-07	311	1 25	0 74	37 6	on
2/17/2003	QP-09	309	0 57	0 30	83 4	on
2/17/2003	QP-10	311	1 09	0 61	90 2	on
2/18/2003	QP-10	332	0 25	<0 06	10 1	off
2/18/2003	QP-11	200	0 16	<0 10	18 7	off
2/18/2003	QP-12	391	0 28	0 13	na	off

Table 17 Summary of Roof level Workers' NTP Exposure Results Jo and George Marti Elementary School			
Exposure Analyte	Mean Concentration		% Difference Afterburner on vs Afterburner off
	Afterburner on	Afterburner off	
NTP TP (mg/m^3)	1 60	0 43	-275
NTP BSF (mg/m^3)	0 74	0 19	-288
NTP Total PAC ($\mu g/m^3$)	104	43 1	-142

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

Statistical analyses were conducted on the NTP-adjusted air sampling data to determine the effectiveness of reducing worker exposure to asphalt fumes by using an afterburner system A summary of these analyses is shown in Table 18 Comparisons were made between air sample results for NTP TP, NTP BSF, and NTP total PAC while the afterburners were off and when the afterburner was on 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, NTP BSF, and NTP total PAC, p-values, t-values, and critical t-values at 95% confidence

Using t distribution, reductions in exposure were tested for statistical significance 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 this level Adjusting the exposure results to NTP did not alter the significance

Table 18 Summary of NTP Statistical Analyses Jo and George Marti Elementary School					
Comparison Group/Analyte	Afterburner Status	Percent Difference in Exposure	p-value	t-value	Critical t at 95% confidence
Kettle Operator/NTP TP	on vs off	73 6	0 07	1 56	2 13
Kettle Operator/NTP BSF	on vs off	-16 9	0 42	-0 23	2 13
Kettle Operator/NTP Total PAC	on vs off	-20 6	0 38	-0 33	2 13
Area Samples Around Kettle/NTP TP	on vs off	73 6	0 07	1 56	1 72
Area Samples Around Kettle/NTP BSF	on vs off	83 8	0 07	1 54	1 72
Area Samples Around Kettle/NTP Total PAC	on vs off	80 6	0 07	1 56	1 72
Roof-Level Workers/NTP TP	on vs off	-275	0 0002	-4 43	1 75
Roof-Level Workers/NTP BSF	on vs off	-287	0 009	-2 65	1 75
Roof-Level Workers/NTP Total PAC	on vs off	-142	0 02	-2 24	1 75

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 at 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 with the afterburner on and off 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 of exposure when the afterburner system was in use

For the kettle operator, only the mean concentration of TP was reduced when the afterburners were on compared to when the afterburners were off The BSF and total PAC concentrations for the kettle operator were higher when the afterburner was on compared to the afterburner off Comparison of the mean area air samples collected around the kettle with the afterburners on to when they were off shows that reductions in exposures of 74%, 84%, and 81% for TP, BSF ,and total PAC, respectively, were measured when the afterburner were on Personal samples were collected on the roof level workers who were mopping and lugging asphalt The results for the roof level show that the mean TP, BSF, and total PAC exposures increased when the afterburners were on

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 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 a reduction was noted for TP The kettle operator's measured exposures were actually higher for BSF and total PAC 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 The fact that reductions were seen in the area air samples when the afterburners were on also indicate that reduction in the kettle operator's exposures when the afterburners were on was possible if the exhaust was redirected The increase in exposure for roof level workers when the afterburners were on would seem to indicate that the afterburner system has little effect in reducing their exposures to asphalt fumes

CONCLUSIONS

Measurements taken on the kettle operator showed a reduction in TP exposure, although this reduction was not statistically significant The kettle operator's BSF and total PAC exposures were elevated when the afterburner system was in use The area air samples all showed a reduction in exposures when the afterburners were on This indicates the reduction in asphalt fume exposure for the kettle operator is possible The roof level workers exposures were also increased when the afterburners were on Further study is needed to determine if afterburner systems could be effective at reducing asphalt fume emissions

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