SURVEY REPORT

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

at

5900 Broadway
San Antonio, Texas

REPORT WRITTEN BY
David A Marlow
Jennifer L Topmiller

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4676 Columbia Parkway, Mail stop R5
Cincinnati, Ohio 45226

FACILITY SURVEYED	Addition to a strip mall 5900 Broadway San Antonio, Texas
SIC CODE	1761
SURVEY DATES	August 30 and 31, 2000
SURVEY CONDUCTED BY	David A Marlow Joe Lasher
FACILITY REPRESENTATIVE	Building was under construction, no facility representative available
CONTRACTOR	Beldon Roofing Company 5039 West Avenue P O Box 13380 San Antonio, Texas 78213 210-341-3100
EMPLOYEE REPRESENTATIVE	No representatives
ANALYTICAL WORK PERFORMED BY	DataChem Laboratories 960 West LeVoy Drive Salt Lake City, Utah 84123-2547

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SUMMARY

On August 30 and 31, 2000, a field survey was conducted at a construction site where a built up asphalt roof was being installed on an addition to a strip mall building at 5900 Broadway Ave 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 under three different scenarios afterburner on and kettle lid closed, afterburner off and kettle lid closed, and afterburner off and kettle lid opened Air samples were collected on the kettle operator, two roof level workers, and 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 opened Reductions in exposures for the kettle operator of 40%, 60%, and 66% for TP, BSF, and total PAC, respectively, were measured Reductions of 76%, 84%, and 85% in TP, BSF, and total PAC, respectively, 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 10%, 23%, and 14%, respectively None of the reductions measured 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

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 of 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 In the past, roofers 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 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 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, 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 and 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 The heat energy is transferred to the asphalt before the gases are 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 removes the paper wrapping and chops 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 to 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 ignite The maximum heating temperature is 50°F less than the FP and should not 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

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 the 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 on August 30 and 31, 2000, at an addition to a strip mall at 5900 Broadway Street in San Antonio, Texas, where a new 3-ply roof with a mineral surface fiberglass cap sheet was installed The engineering control used during this evaluation was a Reeves afterburner system Other existing engineering controls for this industry will be evaluated during subsequent surveys A final report will summarize all of the engineering controls evaluated in this study

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 [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 fume 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 indicate that roofing asphalt fume condensates generated in the laboratory and applied dermally cause benign and malignant skin tumors in several strains of mice [27 33, 34] 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 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

SITE DESCRIPTION AND WORK ACTIVITY

This survey was conducted at 5900 Broadway St in San Antonio, Texas, where a new store addition was being constructed to an existing strip mall The roof being applied was a 3-ply built-up asphalt roof with a mineral surface fiberglass cap sheet Table 2 shows the amount of asphalt used each day of the survey

Table 2 Amount of Asphalt Used Each Day

Date	Amount of Asphalt Used (pounds)
8/30/2000	6400
8/31/2000	100

The roofers began work at 6 30 a m both days At that time, the kettle operator loaded asphalt into the kettle and lit the propane burners to bring the asphalt up to the correct temperature The kettle used was a 650 gallon kettle manufactured by Reeves and equipped with two afterburners and safety loading doors The kettle was located at ground level in front of the new addition to the strip mall During the two days that the survey was conducted, the roofers worked on an area of the roof where 1-ply of asphalt and felt had been previously applied to insulation board The roofers applied two more layers of asphalt and felt and capped the three layers with a mineral surface fiberglass cap sheet

EVALUATION METHODS

To develop useful and practical recommendations, the ability of the engineering control 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 The safety loading kettle lid was either open or closed Personal breathing zone and area air samples were collected and analyzed for total particulate (TP), benzene soluble fraction (BSF) of the total particulate using NIOSH Manual of Analytical Methods (NMAM) Method 5042, and NMAM Method 5800 for PACs [36] The temperature of the hot asphalt was recorded periodically with an electronic thermocouple and compared to the temperature gauge 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 was used to collect total PACs Both sampling trains' air sampling pumps were calibrated to a 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 with the sampling media 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

Summarized in Table 3 for the first day of sampling is the mean kettle temperature measurement along with the mean kettle gauge temperature measurement No temperature measurements were made during the second day of the survey

Table 3. Kettle Temperature Data

Date	Number of Measurements	Mean Kettle Temperature (°F)	Minimum Kettle Temperature (°F)	Maximum Kettle Temperature (°F)	Mean Gauge Kettle Temperature (°F)
8/30/2000	2	490	483	497	510

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, with afterburners off and the kettle lid closed, and afterburner off and the kettle lid open 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

RESULTS

Kettle Operator Personal Breathing Zone Sample Results

Personal breathing zone air samples were collected on the kettle operator (JP-01) and analyzed for TP, BSF, and total PAC Samples were collected for two days, and the results are listed in Table 4 and summarized in Table 5 During the two days of sampling, the kettle lid equipped with two afterburners and safety loading doors was set for three different conditions 1) afterburner off and kettle lid open, 2) afterburner off and kettle lid closed, and 3) afterburner on and kettle lid closed

Table 4 Kettle Operator Exposure Concentrations

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
8/30/00	105	2 11	1 62	331	80 1	411	afterburner off, lid open
8/31/00	43	0 24	0 33	7 33	<1 22	8 19	afterburner off, lid open
8/30/00	116	0 84	0 58	72 5	28 7	101	afterburner off, lid closed
8/30/00	32	0 63	0 16	38 0	9 92	47 9	afterburner off, lid closed
8/30/00	121	0 93	0 68	104	25 8	129	afterburner on, lid closed
8/30/00	150	0 47	<0 14	8 04	5 25	13 3	afterburner on, 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 Exposure Results

Exposure Analyte	Mean Concentration			% Difference		
	off/open Mean Conc	off/closed Mean Conc	on/closed Mean Conc	off/open vs off/closed	off/open vs on/closed	off/closed vs on/closed
TP (mg/m^3)	1 17	0 73	0 70	37 2	39 9	4 13
BSF (mg/m^3)	0 97	0 37	0 39	62 2	60 2	-5 24
Total PAC ($\mu g/m^3$)	210	74 6	71 3	64 4	66 0	4 33

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 During the two days of sampling, the area air samples were collected when the kettle was set for three different conditions 1) afterburner off and kettle lid open, 2) afterburner off and kettle lid closed, and 3) afterburner on and kettle lid closed These results are shown in Table 6 and summarized in Table 7

Table 6 Area Air Sample Concentration Results Collected Around the Kettle								
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 ($\mu g/m^3$)	Kettle Conditions
8/30/2000	NE corner	119	0 04	0 03	18 9	3 51	22 4	afterburner off, lid open
8/30/2000	NW corner	121	0 84	0 54	161	38 0	199	afterburner off, lid open
8/30/2000	SE corner	121	4 56	4 39	2841	874	3715	afterburner off, lid open
8/30/2000	SW corner	118	0 04	0 03	5 25	0 44	5 69	afterburner off, lid open
8/30/2000	NE corner	115	0 04	0 03	12 7	2 27	15 0	afterburner off, lid closed
8/30/2000	NE corner	24	0 21	<0 86	6 53	<8 71	12 7	afterburner off, lid closed
8/30/2000	NW corner	118	0 23	0 03	28 9	9 19	38 1	afterburner off, lid closed
8/30/2000	NW corner	18	0 93	0 28	<2 87	<11 5	<14 4	afterburner off, lid closed
8/30/2000	SE corner	117	0 30	0 13	58 3	21 3	79 6	afterburner off, lid closed
8/30/2000	SE corner	17	1 44	0 60	162	65 4	227	afterburner off, lid closed
8/30/2000	SW corner	116	0 09	0 09	<0 44	<1 78	<2 22	afterburner off, lid closed
8/30/2000	SW corner	15	0 48	<1 36	<3 44	<13 8	<17 3	afterburner off, lid closed
8/30/2000	NE corner	127	0 12	0 03	19 4	3 29	22 6	afterburner on, lid closed
8/31/2000	NE corner	151	0 10	<0 14	9 51	1 60	11 1	afterburner on, lid closed
8/30/2000	NW corner	127	0 44	0 13	45 4	15 4	60 8	afterburner on, lid closed
8/31/2000	NW corner	151	0 03	<0 13	4 55	<0 35	4 80	afterburner on, lid closed
8/30/2000	SE corner	128	1 64	1 12	867	231	1098	afterburner on, lid closed
8/31/2000	SE corner	151	0 16	0 07	7 18	0 34	7 53	afterburner on, lid closed
8/30/2000	SW corner	129	0 16	0 02	0 80	<0 40	1 08	afterburner on, lid closed
8/31/2000	SW corner	150	0 03	<0 13	3 00	<0 48	3 34	afterburner on, lid closed

Table 7 Summary of the Area Air Sample Results						
Exposure Analyte	Mean Concentration			% Difference		
	off/open	off/closed	on/closed	off/open vs off/closed	off/open vs on/closed	off/closed vs on/closed
TP (mg/m^3)	1 37	0 47	0 34	66 0	75 6	28 2
BSF (mg/m^3)	1 25	0 34	0 21	72 7	83 6	39 8
Total PAC ($\mu g/m^3$)	986	54 9	151	94 4	84 7	-205

Roof Level Worker Personal Breathing Zone Sample Results

Personal breathing zone air samples were collected on the roof level workers who were putting on the new roof Three workers who were mopping were sampled for TP, BSF, and total PAC for two days During the two days of sampling, the kettle lid equipped with two afterburners and safety loading doors was set for three different conditions 1) afterburner off and kettle lid open, 2) afterburner off and kettle lid closed, and 3) afterburner on and kettle lid closed These sample results are shown in Table 8 and summarized in Table 9

Table 8 Roof-Level Worker Exposure Concentrations								
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 ($\mu g/m^3$)	Kettle Conditions
8/30/00	JP-02	102	0 50	0 25	286	61 2	348	afterburner off, lid off
8/31/00	JP-02	49	0 38	0 31	17 4	4 35	21 8	afterburner off, lid off
8/30/00	JP-02	119	0 13	0 11	14 5	2 64	17 2	afterburner off, lid on
8/30/00	JP-02	28	0 36	0 06	37 5	7 49	44 9	afterburner off, lid on
8/30/00	JP-02	124	0 12	0 03	164	36 8	200	afterburner on, lid on
8/31/00	JP-03	112	0 29	<0 18	11 9	2 62	14 5	afterburner on, lid on
8/30/00	JP-03	100	0 86	0 46	163	40 0	203	afterburner off, lid off
8/30/00	JP-03	117	0 35	0 17	34 2	14 5	48 7	afterburner off, lid on
8/30/00	JP-03	32	0 17	0 21	49 7	9 62	59 3	afterburner off, lid on
8/30/00	JP-03	120	0 85	0 63	208	46 6	255	afterburner on, lid on

8/30/00	JP-04	97	0 90	0 42	118	29 2	147	afterburner off, lid off
8/31/00	JP-04	49	0 46	0 42	44 8	17 1	61 9	afterburner off, lid off
8/30/00	JP-04	116	0 22	0 01	38 5	14 0	52 5	afterburner off, lid on
8/30/00	JP-04	30	0 44	0 06	21 0	3 50	24 5	afterburner off, lid on
8/30/00	JP-04	124	0 94	0 74	147	33 9	181	afterburner on, lid on
8/31/00	JP-04	146	0 19	0 10	16 5	5 73	22 2	afterburner on, lid on
8/31/00	JP-05	48	0 39	0 33	22 1	8 27	30 3	afterburner off, lid off
8/31/00	JP-05	144	0 74	0 04	14 7	8 82	23 5	afterburner on, lid on

Table 9 Summary of the Roof-Level Worker Exposure Results

Exposure Analyte	Mean Concentration			% Difference		
	off/open	off/closed	on/closed	off/open vs off/closed	off/open vs on/closed	off/closed vs on/closed
TP (mg/m^3)	0 58	0 28	0 52	52 3	10 2	-88 1
BSF (mg/m^3)	0 36	0 10	0 28	71 2	23 0	-167
Total PAC ($\mu g/m^3$)	135	41 2	116	69 5	14 1	-181

Statistical Analysis of the Effectiveness of Using an Afterburner System with a Safety Loading Door 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 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 while the afterburners were off and the kettle lid was open, when the afterburner was off and the kettle lid was closed, and when the afterburner was on 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 reductions in exposure to the mean TP, BSF, and total PAC concentrations, p-values, t-values, and critical t-values at 95% confidence

Using a 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 of the Effectiveness of Using An Afterburner System with a Safety Loading Door to Reduce Worker and Area Air Exposures

Comparison Group/Analyte	Afterburner/ Kettle lid Condition	Percent Difference in Exposure	p-value	t-value	Critical t at 95% confidence
Kettle Operator/TP	off/open vs off/closed	37 3	0 34	0 46	2 92
Kettle Operator/TP	off/open vs on/closed	39 9	0 34	0 48	2 92
Kettle Operator/TP	off/closed vs on/closed	4 13	0 46	0 12	2 92
Kettle Operator/BSF	off/open vs off/closed	62 2	0 23	0 90	2 92
Kettle Operator/BSF	off/open vs on/closed	60 2	0 25	0 83	2 92
Kettle Operator/BSF	off/closed vs on/closed	-5 24	0 48	-0 05	2 92
Kettle Operator/Total PAC	off/open vs off/closed	64 4	0 29	0 66	2 92
Kettle Operator/Total PAC	off/open vs on/closed	66 0	0 29	0 66	2 92
Kettle Operator/Total PAC	off/closed vs on/closed	4 33	0 48	0 05	2 92
Area Samples Around Kettle/TP	off/open vs off/closed	66 0	0 13	1 18	1 81
Area Samples Around Kettle/TP	off/open vs on/closed	75 6	0 11	1 34	1 81
Area Samples Around Kettle/TP	off/closed vs on/closed	28 2	0 31	0 51	1 76
Area Samples Around Kettle/BSF	off/open vs off/closed	72 7	0 12	1 25	1 81
Area Samples Around Kettle/BSF	off/open vs on/closed	83 6	0 09	1 43	1 81
Area Samples Around Kettle/BSF	off/closed vs on/closed	39 8	0 23	0 76	1 76
Area Samples Around Kettle/Total PAC	off/open vs off/closed	94 4	0 10	1 41	1 81
Area Samples Around Kettle/Total PAC	off/open vs on/closed	84 7	0 11	1 30	1 81
Area Samples Around Kettle/Total PAC	off/closed vs on/closed	-205	0 24	-0 74	1 76
Roof-Level Workers/TP	off/open vs off/closed	52 3	0 01	**2 78**	1 81
Roof-Level Workers/TP	off/open vs on/closed	10 2	0 37	0 34	1 81
Roof-Level Workers/TP	off/closed vs on/closed	-88 1	0 07	-1 57	1 81
Roof-Level Workers/BSF	off/open vs off/closed	71 2	0 0001	**5 58**	1 81

Table 10 Summary of Statistical Analyses of the Effectiveness of Using An Afterburner System with a Safety Loading Door to Reduce Worker and Area Air Exposures					
Comparison Group/Analyte	Afterburner/ Kettle lid Condition	Percent Difference in Exposure	p-value	t-value	Critical t at 95% confidence
Roof-Level Workers/BSF	off/open vs on/closed	23 0	0 28	0 61	1 81
Roof-Level Workers/BSF	off/closed vs on/closed	-167	0 11	-1 30	1 81
Roof-Level Workers/Total PAC	off/open vs off/closed	69 5	0 05	**1 82**	1 81
Roof-Level Workers/Total PAC	off/open vs on/closed	14 1	0 39	0 28	1 81
Roof-Level Workers/Total PAC	off/closed vs on/closed	-182	0 06	-1 68	1 81

Bold = statistically significant reduction at 95% confidence level.

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 two days of sampling are shown in Table 11

Table 11 Summary of Ambient Air Temperature and Pressure Measurements			
Date	Time of Day	Ambient Air Temperature (°F)	Barometric Pressure (in Hg)
8/30/00	7 43 AM	83	29 21
8/30/00	9 04 AM	85	29 21
8/30/00	10 32 AM	84	29 21
8/30/00	1 13 PM	96	29 17
8/30/00	2 14 PM	103	29 13
8/30/00	4 18 PM	99	29 09
8/31/00	8 33 AM	85	29 13
8/31/00	9 45 AM	85	29 17

Table 11. Summary of Ambient Air Temperature and Pressure Measurements			
Date	Time of Day	Ambient Air Temperature (°F)	Barometric Pressure (in Hg)
8/31/00	11 10 AM	90	29 17
8/31/00	12 54 PM	98	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 Table 15 for the area air samples collected around the kettle, and Table 16 and Table 17 for the roof level workers By adjusting to NTP, data collected under different weather conditions from different sites can be more readily compared

Table 12 Kettle Operator Exposure Concentrations						
Sample Date	Ambient Air Temperature (°F)	Barometric Pressure (in Hg)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc ($\mu g/m^3$)	Kettle Conditions
8/30/00	90	29 21	2 01	1 65	383	afterburner off, lid off
8/31/00	98	29 13	0 19	0 19	9 73	afterburner off, lid off
8/30/00	99	29 13	0 77	0 55	93 4	afterburner off, lid on
8/30/00	99	29 09	0 54	0 19	48 1	afterburner off, lid on
8/30/00	100	29 17	0 87	0 73	118	afterburner on, lid on
8/31/00	88	29 17	0 44	<0 11	12 7	afterburner on, lid on

Table 13 Summary of the Kettle Operator Exposure Results						
Exposure Analyte	Mean Concentration			% Difference		
	off/open	off/closed	on/closed	off/open vs off/closed	off/open vs on/closed	off/closed vs on/closed
NTP TP (mg/m^3)	1 10	0 66	0 66	40 2	40 1	-0 29
NTP BSF (mg/m^3)	0 92	0 37	0 37	59 5	59 9	1 13
NTP Total PAC ($\mu g/m^3$)	196	70 8	65 3	63 9	66 7	7 65

Table 14 Area Air Sample Concentration NTP Results Collected Around the Kettle							
Sample Date	Sample Location Around Kettle	Ambient Air Temperature (°F)	Barometric Pressure (in Hg)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc ($\mu g/m^3$)	Kettle Conditions
8/30/2000	NE corner	84	29 21	0 04	0 04	21 4	afterburner off, lid off
8/30/2000	NW corner	84	29 21	0 80	0 61	190	afterburner off, lid off
8/30/2000	SE corner	84	29 21	4 35	4 28	3541	afterburner off, lid off
8/30/2000	SW corner	84	29 21	0 04	0 03	5 42	afterburner off, lid off
8/30/2000	NE corner	101	29 13	0 04	0 01	15 3	afterburner off, lid on
8/30/2000	NE corner	99	29 09	0 20	<0 20	11 5	afterburner off, lid on
8/30/2000	NW corner	101	29 13	0 22	0 08	37 9	afterburner off, lid on
8/30/2000	NW corner	99	29 09	0 85	0 37	93 2	afterburner off, lid on
8/30/2000	SE corner	101	29 13	0 28	0 22	37 9	afterburner off, lid on
8/30/2000	SE corner	99	29 09	1 34	0 64	363	afterburner off, lid on
8/30/2000	SW corner	101	29 13	0 08	0 09	<2 37	afterburner off, lid on
8/30/2000	SW corner	99	29 09	0 45	<0 30	<18 3	afterburner off, lid on
8/30/2000	NE corner	96	29 17	0 09	0 01	21 1	afterburner on, lid on
8/31/2000	NE corner	85	29 13	0 10	<0 10	10 6	afterburner on, lid on
8/30/2000	NW corner	96	29 17	0 40	0 21	56 6	afterburner on, lid on

Table 14 Area Air Sample Concentration NTP Results Collected Around the Kettle							
Sample Date	Sample Location Around Kettle	Ambient Air Temperature (°F)	Barometric Pressure (in Hg)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc ($\mu g/m^3$)	Kettle Conditions
8/31/2000	NW corner	85	29 13	0 05	<0 05	4 49	afterburner on, lid on
8/30/2000	SE corner	96	29 17	1 52	1 13	1025	afterburner on, lid on
8/31/2000	SE corner	85	29 13	0 14	0 10	10 6	afterburner on, lid on
8/30/2000	SW corner	96	29 17	0 09	0 01	0 90	afterburner on, lid on
8/31/2000	SW corner	85	29 13	0 02	<0 02	3 00	afterburner on, lid on

Table 15 Summary of the Area Air Sample NTP Exposure Results						
Exposure Analyte	Mean Concentration			% Difference		
	off/open	off/closed	on/closed	off/open vs off/closed	off/open vs on/closed	off/closed vs on/closed
NTP TP (mg/m^3)	1 31	0 43	0 31	66 8	76 6	29 5
NTP BSF (mg/m^3)	1 26	0 19	0 20	84 8	83 9	-5 54
NTP Total PAC ($\mu g/m^3$)	939	81 0	141	91 4	85 0	-74 3

Table 16 Roof-Level Worker NTP Exposure Concentrations							
Sample Date	Worker ID Number	Ambient Air Temperature (°F)	Barometric Pressure (in Hg)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc ($\mu g/m^3$)	Kettle Conditions
8/30/00	JP-02	84	29 21	0 48	0 35	331	afterburner off, lid off
8/31/00	JP-02	98	29 17	0 32	0 32	20 3	afterburner off, lid off
8/30/00	JP-02	101	29 13	0 12	0 20	17 2	afterburner off, lid on

Table 16 Roof-Level Worker NTP Exposure Concentrations							
Sample Date	Worker ID Number	Ambient Air Temperature (°F)	Barometric Pressure (in Hg)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc ($\mu g/m^3$)	Kettle Conditions
8/30/00	JP-02	99	29 09	0 29	0 05	47 1	afterburner off, lid on
8/30/00	JP-02	96	29 17	0 11	0 12	187	afterburner on, lid on
8/31/00	JP-02	90	29 17	0 26	<0 16	13 9	afterburner on, lid on
8/30/00	JP-03	84	29 21	0 97	0 55	193	afterburner off, lid off
8/30/00	JP-03	101	29 13	0 32	0 25	46 6	afterburner off, lid on
8/30/00	JP-03	99	29 09	0 62	0 19	59 8	afterburner off, lid on
8/30/00	JP-04	84	29 21	0 79	0 68	238	afterburner off, lid off
8/31/00	JP-04	98	29 13	0 84	0 52	140	afterburner off, lid off
8/30/00	JP-04	101	29 13	0 20	0 10	50 2	afterburner off, lid on
8/30/00	JP-04	99	29 09	0 37	0 05	22 8	afterburner off, lid on
8/30/00	JP-04	96	29 17	0 88	0 78	169	afterburner on, lid on
8/31/00	JP-04	90	29 17	0 17	0 01	21 2	afterburner on, lid on
8/31/00	JP-05	98	29 13	0 32	0 03	27 7	afterburner off, lid off
8/31/00	JP-05	90	29 17	0 69	0 04	22 5	afterburner on, lid on

Table 17 Summary of the Roof-Level Worker NTP Exposure Results						
Exposure Analyte	Mean Concentration			% Difference		
	off/open	off/closed	on/closed	off/open vs off/closed	off/open vs off/closed	off/closed vs off/closed
TP (mg/m^3)	0 55	0 32	0 49	42 3	12 2	-52 0
BSF (mg/m^3)	0 36	0 14	0 27	61 4	24 4	-95 6
Total PAC ($\mu g/m^3$)	128	40 6	108	68 3	15 5	-167

Statistical Analysis of the Effectiveness of using Low Fuming Asphalt 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 off and the kettle lid was open, when the afterburner was off and the kettle lid was closed, and when the afterburner was on 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 reductions in exposure to the mean NTP TP, BSF, and total PAC, p-values, t-values, and critical t-values at 95% confidence

Using a 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 reductions' significance

Table 18 Summary of Statistical Analyses of the Effectiveness of Using An Afterburner System With a Safety loading Door to Reduce Worker and Area Air 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	off/open vs off/closed	40 2	0 34	0 48	2 92
Kettle Operator/NTP TP	off/open vs on/closed	40 1	0 34	0 47	2 92
Kettle Operator/NTP TP	off/closed vs on/closed	-0 29	0 50	-0 008	2 92
Kettle Operator/NTP BSF	off/open vs off/closed	59 5	0 27	0 73	2 92
Kettle Operator/NTP BSF	off/open vs on/closed	59 9	0 28	0 68	2 92
Kettle Operator/NTP BSF	off/closed vs on/closed	1 13	0 50	0 01	2 92
Kettle Operator/NTP Total PAC	off/open vs off/closed	63 9	0 29	0 67	2 92
Kettle Operator/NTP Total PAC	off/open vs on/closed	66 7	0 28	0 68	2 92
Kettle Operator/NTP Total PAC	off/closed vs on/closed	7 65	0 47	0 09	2 92
Area Samples Around Kettle/NTP TP	off/open vs off/closed	66 8	0 13	1 20	1 81

Table 18 Summary of Statistical Analyses of the Effectiveness of Using An Afterburner System With a Safety loading Door to Reduce Worker and Area Air Exposures to Asphalt Fumes					
Comparison Group/Analyte	Afterburner/ Kettle lid Condition	Percent Difference in Exposure	p-value	t-value	Critical t at 95% confidence
Area Samples Around Kettle/NTP TP	off/open vs on/closed	76 6	0 10	1 36	1 81
Area Samples Around Kettle/NTP TP	off/closed vs on/closed	29 5	0 30	0 54	1 76
Area Samples Around Kettle/NTP BSF	off/open vs off/closed	84 8	0 09	1 56	1 81
Area Samples Around Kettle/NTP BSF	off/open vs on/closed	83 9	0 08	1 50	1 81
Area Samples Around Kettle/NTP BSF	off/closed vs on/closed	-5 54	0 47	-0 07	1 76
Area Samples Around Kettle/NTP Total PAC	off/open vs off/closed	91 4	0 09	1 46	1 81
Area Samples Around Kettle/NTP Total PAC	off/open vs on/closed	85 0	0 11	1 31	1 81
Area Samples Around Kettle/NTP Total PAC	off/closed vs on/closed	-74 3	0 33	-0 44	1 76
Roof-Level Workers/NTP TP	off/open vs off/closed	42 3	0 06	1 75	1 81
Roof-Level Workers/NTP TP	off/open vs on/closed	12 2	0 36	0 38	1 81
Roof-Level Workers/NTP TP	off/closed vs on/closed	-52 0	0 16	-1 05	1 81
Roof-Level Workers/NTP BSF	off/open vs off/closed	61 4	0 01	2 66	1 81
Roof-Level Workers/NTP BSF	off/open vs on/closed	24 5	0 30	0 54	1 81
Roof-Level Workers/NTP BSF	off/closed vs on/closed	-95 6	0 20	-0 90	1 81
Roof-Level Workers/NTP Total PAC	off/open vs off/closed	68 3	0 05	1 77	1 81
Roof-Level Workers/NTP Total PAC	off/open vs on/closed	15 5	0 38	0 31	1 81
Roof-Level Workers/NTP Total PAC	off/closed vs on/closed	-167	0 07	-1 63	1 81

DISCUSSION

The highest exposures to TP, BSF, and total PAC were measured on the kettle operator and area air samples collected around the kettle while the afterburner was off and the kettle lid was open 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 Reductions in exposures of 40%, 60%, and 66% for TP, BSF, and total PAC, respectively, were measured for the kettle operator when the afterburner was on and the kettle lid was closed compared to when the afterburner was off and the kettle lid was open Similarly, the mean exposure concentrations for the four area air samples collected around

the kettle had reductions of 76%, 84%, and 85% in TP, BSF, and total PAC exposures, respectively, when the afterburner was on and the lid was closed compared to exposures measured while the afterburner was off and the lid was open For the roof level workers, exposures to TP, BSF, and PAC were reduced 10%, 23%, and 14% respectively None of these reductions, for the kettle operator, the roof level workers, or the area samples around the kettle, were statistically significant at the 95% confidence level

The greatest reductions measured were for the condition with the afterburner on and the kettle lid closed The area samples taken around the kettle showed the highest percent reductions Although the reductions were not statistically significant, they were sizable reductions that could aid in limiting worker exposure to asphalt fumes The lack of statistical significance may have been due to the relatively small number of samples collected over this two day period

Adjusting the collected data to normal temperature and pressure did not have much impact on the measured reductions This was done to allow this data to be compared with data collected at other sites under different weather conditions

CONCLUSIONS

This survey was conducted at a roofing site that had an asphalt kettle equipped with afterburners and a safety loading door The greatest reductions in asphalt component exposures occurred when the afterburners were on and the kettle lid was closed as compared to results with the afterburner off and the lid open Although these reductions were not statistically significant at the 95% confidence level, they were substantial and could indicate increased worker protection The sample size was relatively small which could explain the lack of statistical significance

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