SURVEY REPORT:

CONTROL TECHNOLOGY EVALUATION FOR CONTROLLING WORKER EXPOSURE TO ASPHALT FUMES FROM ROOFING KETTLES: KETTLE OPERATED USING LOW FUMING ASPHALT

AT

Blue Valley West High School
Stilwell, Kansas

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FACILITY SURVEYED:	Blue Valley West High School 16200 Antioch Rd Stilwell, Kansas 66085
SIC CODE:	1761
SURVEY DATES:	January 23-25, 2001
SURVEY CONDUCTED BY:	David A Marlow Daniel S Watkins Mike Franzen, Owen Corning
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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 objectives of these studies were 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 to create an awareness of the usefulness and availability of effective hazard control measures

One industry identified for EPHB control studies is the asphalt roofing industry 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

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 As a result of the epidemiological data and this increased potential for exposure, researchers from EPHB developed a project to evaluate engineering controls in the asphalt roofing industry This research 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 [17] 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 [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 is examining urine biomarkers and PAC/Pyrene exposure

Kettle operators are responsible for maintaining the appropriate supply of hot asphalt at the correct temperature for application on the roof during construction of built-up roofs (BUR) BURs are layers or plies of fiberglass felt sealed together with hot asphalt The layers provide protection against moisture penetration and, combined with the asphalt's ability to seal itself, 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 redistributes 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 into 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 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 with 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 The flashpoint (FP) is the temperature at which the asphalt may burst into flame 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 shows the EVT and other thermal properties for four types of asphalt

Table 1
Maximum Heating Temperature, Flashpoint, and EVT 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, a private professional society, 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[28,33,34] 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 [17] 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

STUDY BACKGROUND

A survey was conducted on January 23-25, 2001, at the Blue Valley West High School in Stilwell, Kansas, where a new 3-ply roof with a mineral surface fiber glass cap sheet was being applied This was a new building under construction The engineering control used during this evaluation was low fuming asphalt, other existing engineering controls for this industry will be evaluated in subsequent surveys A final report will summarize the engineering controls evaluated from all of the surveys

SITE DESCRIPTION AND WORK ACTIVITY

The Blue Valley West High School is a large multiple wing school that was under construction when the survey was conducted During this time, the roof over the swimming pool area was being installed The roof being applied consisted of two layers of polyisocyanurate installation board, a layer of Perlite board, 3-plys 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)	Type of Asphalt Used
1/23/01	6000	Conventional
1/24/01	3900	Conventional
1/25/01	1500	Low fuming

Sampling was conducted for three days On the first two days conventional type III asphalt was used On the third day TruMelt™ low fuming type III asphalt was used TruMelt™ low fuming asphalt contains up to 1% of a blend of polymers The addition of the polymers to the asphalt forms a steady-state surface layer that reduces the release of fumes from the asphalt into the air The roofers began work at 7 00 a m each day At that time, the kettle operator loaded asphalt into a kettle and lit the propane burners to begin bringing the asphalt up to the correct temperature On the first day, a 1200 gallon Panther kettle was used On the second day, a 600 gallon Garlock kettle was used A 600 gallon Panther kettle was used on the third day of sampling The 600 gallon Panther kettle used on the third day was approximately half full with conventional asphalt The kettle operator filled the kettle to the top with TruMelt™ at 8 00 AM A complete crust over the surface of the asphalt was not achieved until 10 00 AM The kettles were located at ground level in front of the swimming pool wing of the high school

EVALUATION METHODS

In order to develop useful and practical recommendations, the ability of the engineering control measure to reduce worker exposure to air contaminants must be documented and evaluated Where practical, this was accomplished by evaluating workers' exposure to asphalt fume particulate and PACs both with and without low fuming asphalt 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 using 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 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' air sampling pumps were calibrated to a nominal 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 was positioned to breathing zone height (approximately 60 inches above the ground) Area air samples were also collected near the hot pipe on the roof These area air samples were also placed on tripods with the sampling media positioned to breathing zone height

Kettle Temperature

The kettle was equipped with a permanently mounted temperature gage This gauge reading was 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

Table 3 shows a summary of the kettle asphalt temperature measurements made during the three days of sampling The maximum kettle temperature was noted to be above the maximum heating temperature, although the mean kettle temperature generally was not On 1/25/2001, the outside air temperature was quite low, which accounts for the higher required kettle temperatures To keep the asphalt at proper application temperature, it was necessary to have a higher kettle temperature

Table 3
Summary of Kettle Temperature Data

Date	Number of Measurements	Minimum Kettle Temperature (°F)	Maximum Kettle Temperature (°F)	Mean Kettle Temperature (°F)	Mean Gauge Kettle Temperature (°F)
1/23/01	4	512	560	534	526
1/24/01	5	510	550	525	497
1/25/01	4	538	568	552	547

Statistical Evaluation

Personal breathing zone and area air sample data for TP, BSF, and total PAC were statistically compared with and without low fuming asphalt using Student's t-test Statistical comparisons were also done for the data normalized by dividing the data by the amount of asphalt used, adjusted to normal temperature and pressure, and the combination of the normalized by dividing the data by the amount of asphalt used and adjusted to normal temperature and pressure

RESULTS

Kettle Operator Sample Results

Personal breathing zone air samples were collected on the kettle operator (KP-04) and analyzed for TP, BSF, and total PAC Samples were collected for three days, and the results are listed in Table 4 Two days of sampling were conducted when the kettle contained conventional asphalt, and one day of sampling was conducted when the kettle contained TruMelt™ low fuming asphalt Table 5 summarizes the mean concentration for the kettle operator for each of the analytes when conventional and low fuming asphalt was used and the percent reduction obtained using the low fuming asphalt

Table 4
Kettle Operator (KP-04) TP, BSF, and PAC Exposure Concentrations

Sample Date	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)	With or Without Low Fuming Asphalt
1/23/01	494	1 92	1 11	194	38 8	233	Without
1/24/01	492	3 15	2 74	462	123	585	Without
1/25/01	447	1 57	0 85	181	46 3	227	With

Table 5
Summary of the Kettle Operator (KP-04) TP, BSF, and Total PAC Exposure Results

	Asphalt Type		
	Conventional	Low Fuming	
Exposure Analyte	Mean Conc	Mean Conc	% Reduction
TP (mg/m^3)	2 53	1 57	38 2
BSF (mg/m^3)	1 93	0 85	58 9
Total PAC ($\mu g/m^3$)	409	227	48 7

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

Area Air Sample Result 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 total PAC two days when conventional asphalt was used in the kettle and one day when low fuming asphalt was used in the kettle These results are shown in Table 6 and summarized in Table 7

Table 6
Area Air Sample Concentration Results For TP, BSF, and PAC Collected Around the Kettle

Sample Date	Sample Location Around Kettle	Sample Location ID Number	Sample Time (min)	TP Conc (mg/m^3)	BSF Conc (mg/m^3)	370 PAC Conc (µg/m^3)	400 PAC Conc (µg/m^3)	Total PAC Conc (µg/m^3)	With or Without Low Fuming Asphalt
1/23/01	NE corner	KA-01	519	0 36	0 19	35 0	6.60	41 6	Without
1/24/01	NE corner	KA-01	183	12 6	11 8	2695	594	3289	Without
1/25/01	NE corner	KA-01	463	4 97	4 43	826	217	1044	With
1/23/01	NW corner	KA-02	519	4 43	4 62	628	131	759	Without
1/24/01	NW corner	KA-02	511	0 11	0 06	4 73	0 72	5.45	Without
1/25/01	NW corner	KA-02	466	0 33	0 15	25 9	6 79	32 7	With
1/23/01	SE corner	KA-03	519	3 77	3 87	436	87 1	523	Without
1/24/01	SE corner	KA-03	176	13 1	11 1	1795	467	2262	Without
1/25/01	SE corner	KA-03	463	3 79	2 16	532	122	654	With
1/23/01	SW corner	KA-04	522	1 52	1 33	222	44 4	266	Without
1/24/01	SW corner	KA-04	511	0 22	0 15	18.6	4 60	23 2	Without
1/25/01	SW corner	KA-04	463	0 65	0 38	87 1	21 8	109	With

Table 7
Summary of Area Air Samples (KA-01 through -04) Collected Around the Kettle TP, BSF, and Total PAC Exposure Results

Exposure Analyte	Asphalt Type: Conventional Mean Conc	Asphalt Type: Low Fuming Mean Conc	% Reduction
TP (mg/m³) (SD)	4 51 (5 39)	2 43 (2 30)	46 1
BSF (mg/m³) (SD)	4 14 (4 83)	1 78 (1 98)	57 0
Total PAC (µg/m³) (SD)	896 (1220)	460 (477)	48 7

Roof Level Worker Sample Results

Personal breathing zone air samples were collected on the roof level workers who were putting on the new roof Two of the workers who were mopping, and one worker who was lugging the asphalt, were sampled for TP, BSF, and total PAC for two days using conventional asphalt and one day using low fuming asphalt Worker KP-03 performed the lugging activities on the roof, filling the lugger with asphalt and using the lugger to fill the mop buckets with asphalt Workers KP-01 and KP-02 performed the asphalt mopping activities on the roof The personal breathing zone air sample data collected from the roof-level workers are shown in Table 8 The mean data for all workers on the roof for each analyte are shown in Table 9 along with the percent reduction

Table 8
Roof-Level Worker TP, BSF, and PAC Exposure Concentrations

Sampling Day	Worker ID Number	Sample Time (hr)	TP Conc (mg/m³)	BSF Conc (mg/m³)	370 PAC Conc (µg/m³)	400 PAC Conc (µg/m³)	Total PAC Conc (µg/m³)	With or Without Low Fuming Asphalt
1/23/01	KP-01	478	0.85	0 58	82 9	15 7	98 6	Without
1/24/01	KP-01	478	0 41	0 26	42 1	7 36	49 4	Without
1/25/01	KP-01	294	0.53	0 32	71 9	17 1	89 1	With
1/23/01	KP-02	470	2 03	0 87	161	31 1	192	Without
1/24/01	KP-02	463	0 30	0 24	34 8	5 88	40 7	Without

1/25/01	KP-02	294	0 86	0 50	116	27 3	143	With
1/23/01	KP-03	472	2 44	2 12	261	52 2	313	Without
1/24/01	KP-03	472	0 77	0 42	117	22 4	140	Without
1/25/01	KP-03	322	1 54	1 23	218	56 0	274	With

Table 9
Summary of Roof Level Workers (KP-01, -02, and -03) TP, BSF, and Total PAC Exposure Results

	Asphalt Type		
Exposure Analyte	Conventional Mean Conc	Low Fuming Mean Conc	% Reduction
TP (mg/m^3) (SD)	1 13 (0 89)	0 97 (0 52)	14 2
BSF (mg/m^3) (SD)	0 79 (0 70)	0 68 (0 48)	13 9
PAC ($\mu g/m^3$) (SD)	139 (102)	169 (94 8)	-21 6

Statistical Analysis of the Effectiveness of using Low Fuming Asphalt 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 low fuming asphalt A summary of these analyses is shown in Table 10 Comparisons were made between air sample results for TP, BSF, and total PAC while conventional asphalt was used to sample results from times when low fuming asphalt was used Comparisons were made for the following groups the kettle operator (KP-04), the four area air samples (KA-01 through -04) collected around the asphalt kettle, and the three roof-level workers (KP-01, -02, and -03) 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-value 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 samples collected around the kettle, or the roof-level worker samples were found to be statistically significant at 95% confidence

Table 10
Summary of Statistical Analyses of the Effectiveness of Using Low Fuming Asphalt to Reduce Worker and Area Air TP, BSF, and Total PAC Exposures

Comparison Group/Analyte	Percent Reduction in Exposure (Conventional - Low fuming)/Conventional	p-value	t-value	Critical t at 95% confidence
Kettle Operator/TP	37 9	0 2640	0 9158	6 3138
Kettle Operator/BSF	56 0	0 2922	0 7647	6 3138
Kettle Operator/Total PAC	44 5	0 3290	0 5958	6 3138
Area Samples Around Kettle/TP	46 1	0 2429	0 7238	1 8125
Area Samples Around Kettle/BSF	57 0	0 1897	0 9198	1 8125
Area Samples Around Kettle/Total PAC	48 7	0 2572	0 6760	1 8125
Roof-Level Workers/TP	14 2	0 3937	0 2801	1 8946
Roof-Level Workers/BSF	13 9	0 4110	0 2335	1 8946
Roof-Level Workers/Total PAC	-21 6	0 3436	-0 4199	1 8946

Comparison of Results by Normalized Exposure Concentrations by the Amount of Asphalt Used that Day

The amount of asphalt used each day varied as shown in Table 2 Because the exposure levels of TP, BSF, and total PAC measured for the workers and area air samples may be affected by the amount of asphalt used each day, TP, BSF, and total PAC concentration for the workers and area air samples collected around the kettle were normalized by dividing these concentrations by the pounds of asphalt used that day These normalized concentrations were then compared, conventional asphalt to low fuming asphalt, to see if the reductions in exposure were statistically significant when normalized Listed in Table 11 and summarized in Table 12 are the normalized TP, BSF, and total PAC concentrations for the kettle operator (KP-04) Listed in Table 13 and summarized in Table 14 are the normalized TP, BSF, and total PAC concentrations for the four area air samples (KA-01 through -04) collected at the four corners of the kettle Listed in Table 15 and summarized in Table 16 are the normalized TP, BSF, and total PAC concentrations for the roof-level workers (KP-01,-02, and, -03)

Table 11
Kettle Operator (KP-04) Normalized TP, BSF, and PAC Exposure Concentrations

Sample Date	Sample Time (min)	Normalized TP Conc (mg/m^3)	Normalized BSF Conc (mg/m^3)	Normalized Total PAC Conc ($\mu g/m^3$)	With or Without Low Fuming Asphalt
1/23/01	494	0 00032	0 00019	0.03877	Without
1/24/01	492	0 00081	0 00070	0 14995	Without
1/25/01	447	0 00104	0 00057	0.15133	With

Table 12
Summary of Kettle Operator (KP-04) Normalized TP, BSF, and Total PAC Exposure Results

Exposure Analyte	Asphalt Type		% Reduction
	Conventional	Low Fuming	
	Mean Normalized Conc	Mean Normalized Conc	
TP (mg/m^3)	0 00056	0 00104	-85 2
BSF (mg/m^3)	0 00044	0 00057	-27 6
Total PAC ($\mu g/m^3$)	0 09436	0 15133	-60 4

Table 13
Normalized TP, BSF, Total PAC Concentrations for Area Air Samples Collected Around the Kettle

Sample Date	Sample Location ID Number	Normalized TP conc / Lb Asphalt used (mg/m^3Lb)	Normalized BSF conc / Lb Asphalt used (mg/m^3Lb)	Normalized Total PAC conc / Lb Asphalt used ($\mu g/m^3Lb$)	With or Without Low Fuming Asphalt
1/23/01	NA-01	0 00006	0 00003	0 00692	without

1/24/01	NA-01	0 00003	0 00002	0 00140	without
1/25/01	NA-01	0 00252	0 00144	0 43566	with
1/23/01	NA-02	0 00074	0 00077	0 12637	without
1/24/01	NA-02	0 00323	0 00302	0 84336	without
1/25/01	NA-02	0 00022	0 00010	0 02178	with
1/23/01	NA-03	0.00063	0 00064	0 08714	without
1/24/01	NA-03	0 00335	0 00284	0 57992	without
1/25/01	NA-03	0 00043	0 00025	0 07257	with
1/23/01	NA-04	0 00025	0 00022	0 04439	without
1/24/01	NA-04	0 00006	0 00004	0 00595	without
1/25/01	NA-04	0 00331	0 00295	0 69567	with

Table 14
Summary of Area Air Samples (KA-01 through -04) Collected Around the Kettle
Normalized TP, BSF and Total PAC Exposure Results

Exposure Analyte	Asphalt Type		% Reduction
	Conventional	Low Fuming	
	Mean Normalized Conc	Mean Normalized Conc	
TP (mg/m³) (SD)	0 00104 (0.00141)	0 00162 (0 00153)	-55 5
BSF (mg/m³) (SD)	0 00095 (0 00126)	0 00119 (0 00132)	-25 2
Total PAC (μg/m³) (SD)	0 21193 (0.31934)	0 30642 (0 31829)	-44 6

Table 15
Roof-Level Worker Normalized TP, BSF, and PAC Exposure Concentrations

Sampling Day	Worker ID Number	Sample Time (hr)	Normalized TP Conc (mg/m³)	Normalized BSF Conc (mg/m³)	Normalized Total PAC Conc (µg/m³)	With or Without Low Fuming Asphalt
1/23/01	KP-01	478	0 00014	0 00010	0 01644	Without
1/24/01	KP-01	478	0 00011	0 00007	0 01267	Without
1/25/01	KP-01	294	0 00035	0 00022	0 05937	With
1/23/01	KP-02	470	0 00034	0 00015	0 03196	Without
1/24/01	KP-02	463	0 00008	0 00006	0 01044	Without
1/25/01	KP-02	294	0 00057	0 00033	0 09552	With
1/23/01	KP-03	472	0 00041	0 00035	0 05215	Without
1/24/01	KP-03	472	0 00020	0 00017	0 03585	Without
1/25/01	KP-03	322	0.00103	0 00082	0 18238	With

Table 16
Summary of Roof Level Workers (KP-01, -02, and -03) Normalized TP, BSF, and Total PAC Exposure Results

Exposure Analyte	Asphalt Type: Conventional Mean Normalized Conc	Asphalt Type: Low Fuming Mean Normalized Conc	% Reduction
TP (mg/m³) (SD)	0 00021 (0 00013)	0 00065 (0 00035)	-208
BSF (mg/m³) (SD)	0 00015 (0 00011)	0 00046 (0 00032)	-206
PAC (µg/m³) (SD)	0 02658 (0 01628)	0 11242 (0 06322)	-323

Statistical Analysis of the Effectiveness of Using Low Fuming Asphalt to Reduce Worker and Area Air Normalized Exposures to Asphalt Fumes

Statistical analysis of the normalized exposure concentrations was conducted in the same manner as exposure concentrations Statistical comparisons were done for the kettle operator (KP-04), the combined results for the three roof-level workers (KP-01, -02, and -03), and the combined results for the four area air samples (KA-01, -02, -03, and -04) collected around the kettle These statistical analyses are listed in Table 17, for each comparison group and each analyte included in the table are the percent reduction in the mean exposure concentration when comparing mean exposure while using conventional asphalt to mean exposures while using low fuming asphalt, the p- and t-values for the reductions, and the critical t-values at 95% confidence

Statistical comparison of the kettle operator's (KP-04) mean normalized TP, BSF, and the total PAC concentration exposures increased when using low fuming asphalt Similarly the area air samples collected around the kettle and the roof level workers mean normalized exposure concentrations to TP, BSF, and total PAC increased in concentration when the low fuming asphalt was used

Table 17
Summary of Statistical Analyses of the Effectiveness of Using Low Fuming Asphalt to Reduce Worker and Area Air Normalized Exposures to Asphalt Fumes

Comparison Group/Analyte	Percent Reduction in Normalized Exposure (Conventional - Low fuming)/Conventional	p-value	t-value	Critical t at 95% confidence
Kettle Operator/Normalized TP	-85 1	0 2290	-1 1415	6 3137
Kettle Operator/Normalized BSF	-27 7	0 4149	-0 2740	6 3137
Kettle Operator/Normalized total PAC	-60 4	0 3300	-0 5916	6 3137
Area samples around kettle/Normalized TP	-55 6	0 2644	-0 6523	1 8125
Area samples around kettle/Normalized BSF	-25 2	0 3832	-0 3054	1 8125
Area samples around kettle/Normalized total PAC	-44 6	0 3195	-0 4837	1 8125
Roof level worker/Normalized TP	-208.1	0 0119	-2 8728	1 8946

Roof level workers/Normalized BSF	-205 4	0 0307	-2 2253	1 8946
Roof level workers/Normalized total PAC	-322 9	0 0063	-3 3271	1 8946

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

Normal temperature and pressure (NTP) are 77°F and 760 mmHg The mean temperature and pressure measurement for the three days of sampling are shown in Table 18

Table 18
Weather Data

Date	Mean Temperature (°F)	Mean Pressure (mmHg)
1/23/01	39 2	740
1/24/01	35 9	743
1/25/01	24 0	744

Using the mean temperature and pressure measurements for each day, the TP, BSF, and PAC exposure results were adjusted to NTP This data is shown in Table 19 and summarized in Table 20 for the kettle operator (KP-04), in Table 21 and summarized in Table 22 for the area air samples collected around the kettle (KA-01 through -04), and in Table 23 and summarized in Table 24 for the roof level workers (KP-01, -02, and -03) By adjusting to NTP, data from different sites can be compared

Table 19
Kettle Operator (KP-04) NTP TP, BSF, and PAC Exposure Concentrations

Sample Date	Sample Time (min)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc ($\mu g/m^3$)	With or Without Low Fuming Asphalt
1/23/01	494	2 02	1 17	244	Without
1/24/01	492	3 33	2 90	619	Without
1/25/01	447	1 70	0 92	247	With

Table 20
Summary of Kettle Operator (KP-04) NTP Exposure Results

Exposure Analyte	Asphalt Type: Conventional Mean NTP Conc	Asphalt Type: Low Fuming Mean NTP Conc	% Reduction
TP (mg/m^3)	2 67	1 70	36 4
BSF (mg/m^3)	2 03	0 92	54 6
Total PAC (µg/m^3)	431	247	42 9

Table 21
Area Air Sample Concentration Results For NTP TP, BSF, and PAC Collected Around the Kettle

Sample Date	Sample Location ID Number	Sample Time (min)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc (µg/m^3)	With or Without Low Fuming Asphalt
1/23/01	NA-01	519	0.37	0 20	43 5	Without
1/24/01	NA-01	183	0 11	0 06	5 77	Without
1/25/01	NA-01	463	4 11	2 35	710	With
1/23/01	NA-02	519	4 64	4 84	794	Without
1/24/01	NA-02	511	13 3	12 5	3482	Without
1/25/01	NA-02	466	0 36	0 16	35 5	With
1/23/01	NA-03	519	3 95	4 05	548	Without
1/24/01	NA-03	176	13 8	11 7	2394	Without
1/25/01	NA-03	463	0 71	0 41	118	With
1/23/01	NA-04	522	1 59	1 39	279	Without
1/24/01	NA-04	511	0 23	0 16	24 6	Without
1/25/01	NA-04	463	5 40	4 81	1133	With

Table 22
Summary of Area Air Samples (KA-01 through -04) collected around the Kettle NTP TP, BSF, and Total PAC Exposure Results

Exposure Analyte	Asphalt Type: Conventional Mean NTP Conc	Asphalt Type: Low Fuming Mean NTP Conc	% Reduction
TP (mg/m^3) (SD)	4 76 (5 71)	2 64 (2 50)	44 5
BSF (mg/m^3) (SD)	4 36 (5 11)	1 93 (2 15)	55 7
Total PAC ($\mu g/m^3$) (SD)	1840 (2563)	499 (519)	47 3

Table 23
Roof-Level Worker NTP TP, BSF, and PAC Exposure Concentrations

Sample Date	Worker ID Number	Sample Time (hr)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc ($\mu g/m^3$)	With or Without Low Fuming Asphalt
1/23/01	KP-01	478	0 89	0 61	103	Without
1/24/01	KP-01	478	0 43	0 28	52 3	Without
1/25/01	KP-01	294	0 57	0 35	96 7	With
1/23/01	KP-02	470	2 12	0 92	201	Without
1/24/01	KP-02	463	0 32	0 25	43 1	Without
1/25/01	KP-02	294	0 93	0 54	156	With
1/23/01	KP-03	472	2 56	2 22	328	Without
1/24/01	KP-03	472	0 80	0 69	148	Without
1/25/01	KP-03	322	1 67	1 34	297	With

Table 24
Summary of Roof Level Workers (KP-01, -02, and -03) NTP TP, BSF, and Total PAC Exposure Results

	Asphalt Type		
	Conventional	Low Fuming	
Exposure Analyte	Mean NTP Conc	Mean NTP Conc	% Reduction
TP (mg/m^3) (SD)	1 19 (0 93)	1 06 (0 56)	10 8
BSF (mg/m^3) (SD)	0 83 (0 73)	0 74 (0 52)	10 2
PAC ($\mu g/m^3$) (SD)	146 (107)	183 (103)	-25 6

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 low fuming asphalt A summary of these analyses is shown in Table 25 Comparisons were made between air sample results for NTP TP, BSF, and total PAC while conventional asphalt was used and when low fuming asphalt was used

Using t distribution, reductions in exposures were tested to determine if they were statistically significant at 95% confidence Adjusting the exposure concentrations to NTP slightly reduced the percent reduction seen for exposure measurements for the kettle operator (KP-04) and for the area air samples collected around the kettle (KA-01 through -04) For the roof level workers, adjusting the exposure concentrations to NTP showed that the roof level workers' exposures increased slightly more when low fuming asphalt was used

Table 25
Summary of Statistical Analyses of the Effectiveness of Using Low Fuming Asphalt to Reduce Worker and Area Air NTP TP, BSF, and Total PAC Exposures

Comparison Group/Analyte	Percent Reduction in Exposure (Conventional - Low fuming)/Conventional	p-value	t-value	Critical t at 95% confidence
Kettle Operator/NTP TP	36 4	0 27	0 86	6 3137
Kettle Operator/NTP BSF	54 6	0 30	0 74	6 3137

Kettle Operator/NTP Total PAC	42 8	0 34	0 57	6 3137
Area Samples Around Kettle/NTP TP	44 5	0 25	0 70	1 8125
Area Samples Around Kettle/NTP BSF	55 7	0 20	0 89	1 8125
Area Samples Around Kettle/NTP Total PAC	47 3	0 26	0 65	1 8125
Roof-Level Workers/NTP TP	10 8	0 42	0 22	1 8946
Roof-Level Workers/NTP BSF	10 2	0 43	0 18	1 8946
Roof-Level Workers/NTP Total PAC	-25 6	0 32	-0 50	1 8946

Comparison of Results by Normalized Exposure Concentrations by the Amount of Asphalt Used for that Day and Adjusted to NTP

The NTP exposure concentrations listed in Tables 19, 21, and 23 were normalized by dividing the NTP exposure concentrations by the amount of asphalt used that day These NTP normalized exposure concentrations are listed in Tables 26, 28, and 30 and summarized in Tables 27, 29, 31 for the kettle operator (KP-04), area air samples (KA-01 through -04) collected around the kettle, and the roof level workers (KP-01, -02, and -03), respectively

Table 26
Kettle Operator (KP-04) NTP Normalized TP, BSF, and PAC Exposure Concentrations

Sample Date	Sample Time (min)	NTP Normalized TP Conc (mg/m³lb)	NTP Normalized BSF Conc (mg/m³lb)	NTP Normalized Total PAC Conc (µg/m³lb)	With or Without Low Fuming Asphalt
1/23/01	494	0 00019	0 00019	0.04061	without
1/24/01	492	0 00070	0 00074	0 15875	without
1/25/01	447	0 00057	0 00062	0.16436	with

Table 27
Summary of Kettle Operator (KP-04) NTP Normalized TP, BSF, and Total PAC Exposure Results

Exposure Analyte	Asphalt Type: Conventional — Mean NTP Normalized Conc	Asphalt Type: Low Fuming — Mean NTP Normalized Conc	% Reduction
TP (mg/m^3)	0 00044	0 00057	-27 6
BSF (mg/m^3)	0 00047	0 00062	-31 2
Total PAC ($\mu g/m^3$)	0 09968	0 16436	-64 9

Table 28
Area Air Sample Concentration Results For NTP Normalized TP, BSF, and PAC Collected Around the Kettle

Sample Date	Sample Location ID Number	Sample Time (min)	NTP Normalized TP Conc (mg/m^3lb)	NTP Normalized BSF Conc (mg/m^3lb)	NTP Normalized Total PAC Conc ($\mu g/m^3lb$)	With or Without Low Fuming Asphalt
1/23/01	KA-01	519	0 00003	0 00003	0.00725	with
1/23/01	KA-02	519	0 00077	0 00081	0 13237	with
1/23/01	KA-03	519	0 00064	0 00067	0 09127	with
1/23/01	KA-04	522	0 00022	0 00023	0 04650	with
1/24/01	KA-01	511	0 00002	0 00002	0 00148	with
1/24/01	KA-02	183	0 00302	0 00320	0 89283	with
1/24/01	KA-03	176	0 00284	0 00301	0 61394	with
1/24/01	KA-04	511	0 00004	0 00004	0 00630	with
1/25/01	KA-01	463	0 00144	0 00157	0 47319	without
1/25/01	KA-02	466	0 00010	0 00011	0 02366	without
1/25/01	KA-03	463	0 00025	0 00027	0 07883	without
1/25/01	KA-04	463	0 00295	0 00321	0 75560	without

Table 29
Summary of Area Air Samples (KA-01 through -04) Collected Around the Kettle NTP Normalized TP, BSF, and Total PAC Exposure Results

Exposure Analyte	Asphalt Type: Conventional Mean NTP Normalized Conc	Asphalt Type: Low Fuming Mean NTP Normalized Conc	% Reduction
TP (mg/m^3) (SD)	0 00095 (0.00150)	0 00119 (0 00167)	-25 2
BSF (mg/m^3) (SD)	0 00100 (0 00133)	0 00129 (0 00144)	-28 8
Total PAC (µg/m^3) (SD)	0.22399 (0 33815)	0 33282 (0 34570)	-48 6

Table 30
Roof-Level Worker NTP Normalized TP, BSF, and PAC Exposure Concentrations

Sample Date	Worker ID Number	Sample Time (min)	NTP Normalized TP Conc (mg/m^3)	NTP Normalized BSF Conc (mg/m^3)	NTP Normalized Total PAC Conc (µg/m^3)	With or Without Low Fuming Asphalt
1/23/01	KP-01	478	0 00010	0 00010	0 01722	without
1/24/01	KP-01	478	0 00007	0 00007	0 01341	without
1/25/01	KP-01	294	0 00022	0 00023	0 06449	with
1/23/01	KP-02	470	0 00015	0 00015	0 03348	without
1/24/01	KP-02	463	0 00006	0 00006	0 01105	without
1/25/01	KP-02	294	0 00033	0 00036	0 10375	with
1/23/01	KP-03	472	0 00035	0 00037	0 05465	without
1/24/01	KP-03	472	0 00017	0 00018	0 03795	without
1/25/01	KP-03	322	0 00082	0 00089	0 19809	with

Table 31
Summary of Roof Level Workers NTP Normalized TP, BSF, and Total PAC Exposure Results

Exposure Analyte	Asphalt Type: Conventional — Mean NTP Normalized Conc	Asphalt Type: Low Fuming — Mean NTP Normalized Conc	% Reduction
TP (mg/m³) (SD)	0.00015 (0 00014)	0 00046 (0 00038)	-206
BSF (mg/m³) (SD)	0 00016 (0 00011)	0 00050 (0 00035)	-217
PAC (µg/m³) (SD)	0 02796 (0 01706)	0.12211 (0 06867)	-337

Statistical Analysis of the Effectiveness of using Low Fuming Asphalt to Reduce Worker and Area Air NTP Normalized TP, BSF, and Total PAC Exposures

Statistical analysis of the NTP normalized exposure concentrations was conducted in the same manner as exposure concentrations Statistical comparisons were done for the kettle operator (KP-04), the combined results for the roof-level workers (KP-01, -02, and -03), and the combined results for the four area air samples (KA-01 through -04) collected around the kettle These statistical analyses are listed in Table 32 For each comparison group and analyte in Table 32, the percent reduction in the mean exposure concentration when comparing mean NTP normalized exposure while using conventional asphalt to mean NTP normalized exposures while using low fuming asphalt, the p- and t-values for the reductions, and the critical t-values at 95% confidence are shown

Table 32
Summary of Statistical Analyses of the Effectiveness of Using Low Fuming Asphalt to Reduce Worker and Area Air Exposures to Asphalt Fumes Adjusted to NTP and Normalized by the Amount of Asphalt Used each Day

Comparison Group/Analyte	Percent Reduction in Exposure (Conventional - Low fuming)/Conventional	p-value	t-value	Critical t at 95% confidence
Kettle Operator/NTP Normalized TP	-27 6	0 41486	-0 27403	6 3137
Kettle Operator/NTP Normalized BSF	-31 2	0 40491	-0 30793	6 3137
Kettle Operator/NTP Normalized Total PAC	-64 9	0 32055	-0.63219	6 3137

Area Samples Around Kettle/NTP Normalized TP	-25 2	0 38316	-0 30540	1 8125
Area Samples Around Kettle/NTP Normalized BSF	-28 8	0 36871	-0 34475	1 8125
Area Samples Around Kettle/NTP Normalized Total PAC	-48 6	0 30654	-0 52193	1 8125
Roof-Level Workers/NTP Normalized TP	-206	0 03070	-2 22532	1 8946
Roof-Level Workers/NTP Normalized BSF	-217	0 02824	-2 28180	1 8946
Roof-Level Workers/NTP Normalized Total PAC	-337	0 00591	-3 37678	1 8946

Statistical comparison of the kettle operator's (KP-04) mean NTP normalized TP, BSF, and total PAC concentration exposures all increased slightly when using low fuming asphalt Similarly the area air samples collected around the kettle and the roof level workers mean NTP normalized exposure concentrations to TP, BSF, and total PAC all increase slightly in concentration when the low fuming asphalt was used

DISCUSSION

The kettle operator's exposures to TP, BSF, and total PAC were reduced by 38%, 56%, and 45%, respectively, when comparing exposures when low fuming asphalt was used to when conventional asphalt was used When exposure concentrations were adjusted for NTP the percent reductions for the kettle operator were 36%, 55%, and 43%, changing the reduction in exposure slightly When the kettle operator's exposure data was normalized exposures to TP, BSF, and total PAC increased by 85%, 28%, and 60% respectively when using low fuming asphalt When the normalized data was adjusted to NTP the increase in exposures was slightly greater These increases in exposure seen when the data was normalized to the amount of asphalt use each day suggests that to some degree the exposure reductions seen when low fuming asphalt was used may be effected by the amount of asphalt used Another possible explanation for this increase in exposure when the data was normalized is that on the third day of sampling when the low fuming asphalt was used, three hours passed before a complete crust of polymer was formed over the surface of the asphalt thereby allowing more asphalt fume to escape in a similar manner as conventional asphalt None of these reductions were statistically significant at 95% confidence

Similar to the results seen for the kettle operator, the mean exposure concentration for TP, BSF, and total PAC were reduced by 46%, 57%, and 49%, respectively, in the area air samples collected around the asphalt roofing kettle when comparing exposure results when low fuming asphalt was used to when conventional asphalt was used When the exposure data was adjusted to NTP, the reductions were slightly less than the unadjusted results Like the kettle operator's results, when the area air sample results were normalized there was increase in exposure when low fuming was used and the increase was slightly more when the normalized area air exposure data was adjusted to NTP None of the reduction were statistically significant at 95% confidence

The mean exposure results for TP and BSF were reduced by 14% and 13%, respectively, in the roof level workers' exposure results when comparing low fuming asphalt exposure data to conventional asphalt exposure data There was an increase of 21% in total PAC exposure results for the roof level workers when using low fuming asphalt NTP data adjustments lowered the TP and BSF reductions in exposure to 11% and 10%, respectively, while the increase in total PAC exposure seen when low fuming asphalt was used was slightly greater at 26% Normalizing the roof level workers' exposure data increased mean TP, BSF, and total PAC exposure concentrations by 208%, 206%, and 323%, respectively, when using low fuming asphalt When the normalized data was adjusted to NTP the increases seen in the roof level workers' exposures were slightly greater when low fuming asphalt was used None of the reduction were statistically significant at 95% confidence

The results of measurements taken when both conventional and low fuming asphalt were used at the same asphalt roofing site indicate that using low fuming asphalt reduces the exposure of the kettle operator to asphalt compounds The area samples and personal samples taken on the kettle operator showed reductions, but none of the reductions measured were statistically significant at 95% confidence Two reasons that the reductions were not statistically significant are that the sample size was too small, and on the day that the TruMelt™ was used, the polymer crust was not fully formed on the asphalt surface until three hours after air sampling had begun

When the results were normalized by dividing by the amount of asphalt used exposures for the kettle operator, area air samples collected around the kettle, and roof level workers all slightly increased indicating that the reduction measured may have been influenced by the amount of asphalt used that day

CONCLUSIONS

From the results of this survey, one conclusion that may be drawn is that in order to collect quality data, the researcher must have some control over the amount of asphalt used each day and the transition between conventional and low fuming asphalt Also, while it appears that using low fuming asphalt reduces operator exposure to the components of asphalt fume, due to the many variables encountered during sampling, the results are not statistically significant

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