SURVEY REPORT:

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

at

Raytheon Corporation
Fort Wayne, Indiana

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SIC CODE:	1761
SURVEY DATES:	September 18 through 21, 2000
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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 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 that of 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 a 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 item 10 2 of the Healthy People 2000 Objectives, the NIOSH National Occupational Research Agenda (NORA), and OSHA priorities [17-19]

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

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

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

Roofing asphalt may be delivered to the work site in solid kegs or in tanker trucks When tanker trucks are used, a roofing kettle may not be necessary unless additional heating is required The more traditional method is to deliver the asphalt in solid, paper-wrapped kegs which weigh approximately 100 pounds During loading, the kettle operator must remove the paper wrapping and chop the solid asphalt keg into smaller, more manageable pieces These pieces are manually loaded into the kettle through a raised kettle lid or, when available, through a "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
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 [21] The OSHA PELs are the only legally enforceable exposure criteria among those listed, and during their development, OSHA must consider the feasibility of controlling exposures in addition to the related health effects In contrast, NIOSH RELs are based primarily on concerns relating to health effects The ACGIH TLVs refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be exposed, day after day, without adverse health effects The ACGIH is a private professional society and states that the TLVs are only guidelines

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

In 1977, NIOSH established an REL of 5 0 mg/m^3 (total particulate) measured as a 15-minute ceiling limit for asphalt fumes to protect against irritation of the serous membrane of the conjunctiva and the mucous membrane of the respiratory tract In 1988, NIOSH (in testimony to the Department of

Labor) recommended that, based on the OSHA cancer policy,[25] asphalt fumes should be considered a potential occupational carcinogen [26] This recommendation was based on information presented in the Niemeier et al study [27] This NIOSH conclusion is based on the collective evidence found in available health effects and exposure data [28]

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

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

In the roofing industry, exposure to asphalt fumes and other related exposures is well documented and studies still continue Several studies have identified increased polycyclic aromatic compounds (PACs) exposure 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

STUDY BACKGROUND

A survey was conducted September 18-21, 2000, at the Raytheon Corporation building in Fort Wayne, Indiana where a 2-ply built-up roof with mineral surface fiber glass cap sheet was being applied on top of the existing roof No tear-off of the old roof was performed 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 Raytheon Corporation building is a large multiple-wing four-story building that houses offices, research facilities, and some manufacturing of electronic components A 2-ply built-up asphalt roof

with mineral surface fiber glass cap sheet was being applied to the existing roof, no tear-off was performed Shown in Table 2 are the roof areas installed and the amount of asphalt used each day of the survey

Table 2
Area of Roof Installed and Amount of Asphalt Used Each Day

Date	Area of Roof Installed (ft^2)	Amount of Asphalt Used (pounds)
9/18/2000	80,000	6000
9/19/2000	80,000	5700
9/20/2000	20,000	2200
9/21/2000	80,000	5600

The roofers began work at 6 30 a m each day At that time, the kettle operator loaded asphalt into a 900 gallon kettle manufactured by Garlock Equipment Company and lit the propane burners to bring the asphalt up to the proper working temperature The kettle was located at ground level on one side of the wing of the four-story building they were roofing During the week that the survey was conducted, the roofers applied a layer of underlay board, two plies of fiberglass felt and capped with mineral surfaced fiberglass cap sheet

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 For this study, 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 PACs using NMAM Method 5800 [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 an air sampling flow rate of 2 liters per minute (lpm) Personal breathing zone air samples were collected on the kettle operator and three roof level workers Area air samples were collected at ground level at each of the four corners around the

kettle The area air samplers were placed on tripods and the sampling media were positioned to breathing zone height (approximately 60 inches above the ground) An area air sample was also collected near the hot pipe on the roof This sampler was also placed on a tripod with the sampling media at breathing zone height

Kettle Temperature

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

Table 3 summarizes the kettle asphalt temperature measurements made during the four days of sampling

Table 3
Summary of Kettle Temperature Data

Date	Number of Measurements	Minimum Kettle Temperature (°F)	Maximum Kettle Temperature (°F)	Mean Kettle Temperature (°F)	Mean Gage Kettle Temperature (°F)
9/18/00	3	476	508	506	475
9/19/00	2	492	519	506	477
9/20/00	3	506	530	518	500
9/21/00	1	509	509	509	433

RESULTS

Kettle Operator Sampling Results

Personal breathing zone air samples were collected on the kettle operator and analyzed for TP, BSF, and total PAC Samples were collected for four days, and the results are listed in Table 4 On all four days of sampling, the kettle contained TruLo™ low fuming asphalt The mean concentration of TP for the kettle operator was 0 55mg/m^3 (SD = 0 32 mg/m^3) The mean BSF concentration for the kettle operator was 0 34 mg/m^3 (SD = 0 26 mg/m^3) The mean total PAC concentration for the kettle operator was 68 µg/m^3 (SD = 57 mg/m^3)

Table 4
Kettle Operator (IP-01) TP, BSF, and PAC 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 ($\mu g/m^3$)
9/18/00	533	0 50	0 26	34	8	42
9/19/00	544	1 01	0 73	122	29	152
9/20/00	346	0 41	0 23	40	11	51
9/21/00	627	0 28	0 16	22	5	27

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

Area 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 for four days when low fuming asphalt was used These results are shown in Table 5

The mean TP concentration for the 16 area air samples collected around the kettle was 0 30 mg/m^3 (SD = 0 24) The mean BSF concentration for the area air samples collected around the kettle was 0 22 mg/m^3 (SD = 0 21) The mean total PAC concentration was 33 $\mu g/m^3$ (SD = 35)

Table 5
Area Air Sample Concentration Results For TP, BSF, and PAC 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 ($\mu g/m^3$)
9/18/2000	NE corner	511	0 17	0 13	13	2 8	16
9/19/2000	NE corner	544	0 37	0 28	24	5 7	30
9/20/2000	NE corner	348	0 37	0 30	41	11	52
9/21/2000	NE corner	613	0 09	0 07	14	3 3	17
9/18/2000	NW corner	511	0 09	0 03	3 4	0 7	4 1
9/19/2000	NW corner	544	0 12	0 04	5 6	0 9	6 5
9/20/2000	NW corner	348	0 07	0 03	2 6	0 4	3 1
9/21/2000	NW corner	613	0 07	0 03	7 8	1 9	10
9/18/2000	SE corner	511	0 51	0 44	0 5	0 6	1 1
9/19/2000	SE corner	544	0 38	0 30	47	11	58
9/20/2000	SE corner	348	0 90	0 78	74	16	90
9/21/2000	SE corner	613	0 70	0 50	99	25	124
9/18/2000	SW corner	511	0 18	0 12	15	3 7	19
9/19/2000	SW corner	544	0 37	0 28	48	11	60
9/20/2000	SW corner	348	0 32	0 20	22	6 2	28
9/21/2000	SW corner	613	0 11	0 05	9 0	2 4	11

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

Roof Level Worker Personal Breathing Zone Sample Results

Personal breathing zone air samples were collected on the roof level workers who were installing the new roof Three workers were sampled one of the workers was mopping, one was either laying down underlay board or rolling out fiber glass felt, and one worker was lugging the asphalt from the hot pipe to the asphalt mop bucket These workers were sampled for TP, BSF, and total PAC for four days of sampling These sample results are shown in Table 6

Table 6
Roof-Level Workers TP, BSF, and PAC Exposure Concentrations

Sample Date	Worker ID Number	Sample Time (hr)	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 ($\mu g/m^3$)
9/18/00	IP-02	215	3 08	2 55	290	66	357
9/19/00	IP-02	238	0 32	0 15	31	6 6	38
9/21/00	IP-02	274	1 26	0 91	179	46	225
9/18/00	IP-03	219	1 08	0 94	113	27	140
9/19/00	IP-03	239	1.12	0.82	148	35	183
9/20/00	IP-03	252	0 09	0 02	9 1	2 0	11
9/21/00	IP-03	266	0 33	0 21	33	8 4	42
9/18/00	IP-04	127	0 85	0 73	91	21	112
9/19/00	IP-04	233	0 39	0 17	32	7 1	39
9/20/00	IP-04	348	0 06	0 01	7 0	0 8	7 7
9/21/00	IP-04	267	0 05	0 04	0 5	0 3	0 8
9/20/00	IP-05	252	0 22	0 12	31	7 6	38 5

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

Worker IP-02 performed the lugging activities for three of the four days sampling was conducted on the roof, filling the lugger with asphalt and using the lugger to fill the mop buckets Worker IP-05 performed the lugging activities for one of the four days of sampling The TP, BSF, and total PAC concentrations for Worker IP-05 were 0 22 mg/m^3, 0 12 mg/m^3, and 39 µg/m^3, respectively Worker IP-02 mean exposure concentrations to TP, BSF, and total PAC was 1 56 mg/m^3, 1 20 mg/m^3, and 207 µg/m^3, respectively Worker IP-03 either mopped or used a spreader to apply asphalt to the roof Worker IP-03's mean exposure concentrations to TP, BSF, and total PAC for the four days of sampling were 0 65 mg/m^3, 0 50 mg/m^3, and 78 µg/m^3, respectively Worker IP-04 was either laying down underlay board or rolling out fiber glass felt on the roof The mean TP, BSF, and total PAC concentrations for Worker IP-04 was 0 43 mg/m^3, 0 24 mg/m^3, and 40 µg/m^3, respectively

The mean TP concentration for all roof-level workers was 0 74 mg/m^3 (SD = 0 86 mg/m^3) The mean BSF concentration for all roof-level workers was 0 56 mg/m^3 (SD = 0 73 mg/m^3) The mean total PAC concentration for all roof-level workers was 100 µg/m^3 (109 µg/m^3)

Kettle Operator Standardized Sample Results

The amount of asphalt used each day varied as shown in Table 2 Because the levels of TP, BSF, and total PAC measured may be affected by the amount of asphalt used, TP, BSF, and total PAC concentrations for the workers and area air samples collected around the kettle were standardized by dividing these concentrations by the number of pounds of asphalt used that day The concentrations listed in Table 4 for the kettle operator were divided by the amount of asphalt used that day, and the results are shown in Table 7

Table 7
Kettle Operator (IP-01) TP, BSF, and PAC Exposure Concentrations Standardized by the Amount of Asphalt Used that Day

Sample Date	Sample Time (min)	TP Conc (mg/m^3 lb)	BSF Conc (mg/m^{3}lb)	370 PAC Conc (µg/m^{3}lb)	400 PAC Conc (µg/m^{3}lb)	Total PAC Conc (µg/m^{3}lb)
9/18/00	533	8 00e-05	4 00e-05	5 67e-03	1 33e-03	7 00e-03
9/19/00	544	1 80e-04	1 30e-04	2 14e-02	5 09e-03	2 67e-02
9/20/00	346	1 90e-04	1 00e-04	1 82e-02	5 00e-03	2 32e-02
9/21/00	627	5 00e-05	3 00e-05	3 93e-03	8 90e-04	4 81e-03

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

Standardized Area Air Sample Results - Kettle

Area air samples results collected around the kettle and shown in Table 5 were divided by the amount of asphalt used each day Table 8 lists the standardized exposure concentrations for the area air samples collected around the kettle The mean standardized TP, BSF, and total PAC concentrations for the area air samples collected around the kettle for four days were 0 00008 mg/m^3lb, 0 00006 mg/m^3lb, and 0 00881 $\mu g/m^3lb$, respectively

Table 8
Area Air Sample Concentration Results For TP, BSF, and PAC Collected Around the Kettle Standardized by the Amount of Asphalt Used that Day

Sample Date	Sample Location Around Kettle	Sample Time (min)	TP Conc (mg/m^3 lb)	BSF Conc (mg/m^3lb)	370 PAC Conc ($\mu g/m^3lb$)	400 PAC Conc ($\mu g/m^3lb$)	Total PAC Conc ($\mu g/m^3lb$)
9/18/00	NE corner	511	2 98e-05	2 28e-05	2 28e-03	4 91e-04	2 81e-03
9/19/00	NE corner	544	6 17e-05	4 67e-05	4 00e-03	9 50e-04	5 00e-03
9/20/00	NE corner	348	1.68e-04	1.36e-04	1 86e-02	5 00e-03	2 36e-02
9/21/00	NE corner	613	1 61e-05	1 25e-05	2 50e-03	5 89e-04	3 04e-03
9/18/00	NW corner	511	1 58e-05	5 26e-06	5 96e-04	1 23e-04	7 19e-04
9/19/00	NW corner	544	2 00e-05	6 67e-06	9 33e-04	1 50e-04	1 08e-03
9/20/00	NW corner	348	3 18e-05	1 36e-05	1 18e-03	1 82e-04	1 41e-03
9/21/00	NW corner	613	1 25e-05	5 36e-06	1 39e-03	3 39e-04	1 79e-03
9/18/00	SE corner	511	8 95e-05	7 72e-05	8 77e-05	1 05e-04	1 93e-04

9/19/00	SE corner	544	6 33e-05	5 00e-05	7 83e-03	1 83e-03	9 67e-03
9/20/00	SE corner	348	4 09e-04	3 55e-04	3 36e-02	7 27e-03	4 09e-02
9/21/00	SE corner	613	1 25e-04	8 93e-05	1 77e-02	4 46e-03	2 21e-02
9/18/00	SW corner	511	3 16e-05	2 11e-05	2 63e-03	6 49e-04	3 33e-03
9/19/00	SW corner	544	6 17e-05	4 67e-05	8 00e-03	1 83e-03	1 00e-02
9/20/00	SW corner	348	1 45e-04	9 09e-05	1 00e-02	2 82e-03	1 27e-02
9/21/00	SW corner	613	1 96e-05	8 93e-06	1 61e-03	4 29e-04	1 96e-03

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^3lb = milligrams per cubic meter of air per pound of asphalt used
$\mu g/m^3lb$ = micrograms per cubic meter of air per pound of asphalt used
nm = nanometers

Standardized Roof Level Worker Sample Results

Personal breathing zone air samples collected on the workers on the roof during the four days of sampling and shown in Table 6 were divided by the amount of asphalt used each day Listed in Table 9 are the standardized exposure concentrations for the personal breathing zone air samples for the roof level workers The mean standardized TP, BSF, and total PAC concentrations for the roof level workers personal breathing zone air samples collected for four days were 0 00013 mg/m^3lb, 0 00010 mg/m^3lb, and 0 01841 $\mu g/m^3lb$, respectively

Table 9
Roof-Level Worker TP, BSF, and PAC Exposure Concentrations Standardized by the Amount of Asphalt Used that Day

Sample Date	Worker ID Number	Sample Time (min)	TP Conc (mg/m^3lb)	BSF Conc (mg/m^3lb)	370 PAC Conc ($\mu g/m^3lb$)	400 PAC Conc ($\mu g/m^3lb$)	Total PAC Conc ($\mu g/m^3lb$)
9/18/00	IP-02	215	5 40e-04	4 00e-04	5 09e-02	1 16e-02	6 26e-02
9/19/00	IP-02	238	5 00e-05	3 00e-05	5 17e-03	1 10e-03	6 33e-03
9/21/00	IP-02	274	2 30e-04	1 60e-04	3 20e-02	8 21e-03	4 02e-02
9/18/00	IP-03	219	1 90e-04	1 60e-04	1 98e-02	4 74e-03	2 46e-02
9/19/00	IP-03	239	1 90e-04	1 40e-04	2 47e-02	5 83e-03	3 05e-02
9/20/00	IP-03	252	4 00e-05	1 00e-05	4 14e-03	9 10e-04	5 05e-03
9/21/00	IP-03	266	6 60e-02	4 20e-02	5 89e-03	1 50e-03	7 50e-03
9/18/00	IP-04	127	1 49e-04	1 28e-04	1 60e-02	3 68e-03	1 96e-02
9/19/00	IP-04	233	6 50e-05	2 83e-05	5 33e-03	1 18e-03	6 50e-03
9/20/00	IP-04	348	2 73e-05	4 55e-06	3 18e-03	3 64e-04	3 50e-03
9/21/00	IP-04	267	8 93e-06	7 14e-06	8 93e-04	5 36e-05	1 43e-04
9/20/00	IP-05	252	1 00e-04	5 45e-05	1 41e-02	3 45e-03	1 75e-02

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^3lb = milligrams per cubic meter of air per pound of asphalt used
$\mu g/m^3lb$ = micrograms per cubic meter of air per pound of asphalt used
nm = nanometers

Atmospheric and Kettle Temperature Measurements

During the four days of sampling, atmospheric air temperature and barometric pressure measurements were made Shown in Table 10 is a summary of these measurements

Table 10
Summary of Ambient Air Temperature and Pressure Measurements

Date	Number of Measurements	Mean Temperature (°F)	Mean Barometric Pressure (mm Hg)
9/18/2000	12	82	742
9/19/2000	9	78	736
9/20/2000	8	76	733
9/21/2000	9	64	741

Normalized Kettle Operator Sample Results

Normal temperature and pressure (NTP) are 77°F (25°C) and 760 mmHg Using the mean temperature and pressure for each day of sampling, personal breathing zone air samples for the kettle operator were adjusted to NTP and are shown in Table 11 The NTP mean concentration of TP for the kettle operator was 0 54mg/m^3 (SD = 0 29 mg/m^3) The NTP mean BSF concentration for the kettle operator was 0 34 mg/m^3 (SD = 0 24 mg/m^3) The NTP mean total PAC concentration for the kettle operator was 66 µg/m^3 (SD = 53 mg/m^3)

Table 11
Kettle Operator (IP-01) TP, BSF, and PAC Exposure Concentrations Adjusted to Normal Temperature and Pressure

Sample Date	Sample Time (min)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP 370 PAC Conc (µg/m^3)	NTP 400 PAC Conc (µg/m^3)	NTP Total PAC Conc (µg/m^3)
9/18/00	533	0 46	0 24	31	8	39
9/19/00	544	0 97	0 70	117	28	145
9/20/00	346	0 40	0 23	40	11	50
9/21/00	627	0 33	0 18	26	6	32

NTP = normal temperature and pressure
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

Area Samples Collected Around The Kettle Adjusted to Normal Temperature and Pressure

Area air samples collected at the four corners of the asphalt roofing kettle at breathing zone height were also adjusted to NTP using the mean temperature and pressure for each day of sampling These adjusted results are shown in Table 12

The NTP mean TP concentration for the 16 area air samples collected around the kettle for the four days of sampling was 0 30 mg/m^3 (SD = 0 25 mg/m^3) The NTP mean BSF concentration for the area air samples collected around the kettle was 0 22 mg/m^3 (SD = 0 21 mg/m^3) The mean total PAC concentration for the area air samples collected around the kettle was 34 $\mu g/m^3$ (SD = 39 $\mu g/m^3$)

Table 12
Area Air Sample Concentration Results For TP, BSF, and PAC Collected Around the Kettle Adjusted to Normal Temperature and Pressure

Sample Date	Sample Location Around Kettle	Sample Time (min)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP 360 PAC Conc ($\mu g/m^3$)	NTP 400 PAC Conc ($\mu g/m^3$)	NTP Total PAC Conc ($\mu g/m^3$)
9/18/00	NE corner	511	0 16	0 12	12	2 6	14
9/19/00	NE corner	544	0 35	0 27	23	5 4	29
9/20/00	NE corner	348	0 36	0 29	40	11	51
9/21/00	NE corner	613	0 11	0 08	16	3 8	20
9/18/00	NW corner	511	0 08	0 03	3 1	0 6	3 8

9/19/00	NW corner	544	0 12	0 04	5 3	0 9	6 2
9/20/00	NW corner	348	0 07	0 03	2 6	0 4	3 0
9/21/00	NW corner	613	0 09	0 04	9 2	2 2	11
9/18/00	SE corner	511	0 47	0 40	0 5	0 6	1 1
9/19/00	SE corner	544	0 36	0 29	45	11	56
9/20/00	SE corner	348	0 88	0 76	72	16	88
9/21/00	SE corner	613	0 82	0 59	116	29	146
9/18/00	SW corner	511	0 16	0 11	14	3 4	17
9/19/00	SW corner	544	0 35	0 27	46	11	57
9/20/00	SW corner	348	0 32	0 20	21	6 1	27
9/21/00	SW corner	613	0 13	0 06	10 6	2 8	13

NTP = normal temperature and pressure
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

Normalized Roof Level Worker Sample Results

Personal breathing zone air samples collected on the roof level workers were adjusted to NTP These sample results are shown in Table 13

The NTP mean TP concentration for all roof-level workers was 0 72 mg/m^3 (SD = 0 81 mg/m^3) The NTP mean BSF concentration for all roof-level workers was 0 54 mg/m^3 (SD = 0 68 mg/m^3) The NTP mean total PAC concentration for all roof-level workers was 98 $\mu g/m^3$ (107 $\mu g/m^3$)

Table 13
Roof-Level Worker TP, BSF, and PAC Exposure Concentrations Adjusted to Normal Temperature and Pressure

Sample Date	Worker ID Number	Sample Time (min)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP 370 PAC Conc ($\mu g/m^3$)	NTP 400 PAC Conc ($\mu g/m^3$)	NTP Total PAC Conc ($\mu g/m^3$)
9/18/20	IP-02	215	2 82	2 34	266	61	327
9/19/20	IP-02	238	0 31	0 14	30	6 3	36
9/21/20	IP-02	274	1 48	1 07	210	54	264
9/18/20	IP-03	219	0 99	0 86	104	25	129
9/19/20	IP-03	239	1 07	0 78	141	33	175
9/20/20	IP-03	252	0 09	0 02	8 9	1 9	11
9/21/20	IP-03	266	0 38	0 25	39	9 9	49
9/18/20	IP-04	127	0 78	0 67	84	19	103
9/19/20	IP-04	233	0 37	0 17	31	6 7	38
9/20/20	IP-04	348	0 05	0 01	6 8	0 8	7 6
9/21/20	IP-04	267	0 05	0 05	0 5	0 3	0 8
9/20/20	IP-05	252	0 22	0 12	31	7 6	38 5

NTP = normal temperature and pressure
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

Kettle Operator Sample Results, Normalized and Standardized

Taking the NTP data for the kettle operator listed in Table 11 and dividing these data by the amount of asphalt used each day of sampling, NTP standardized personal breathing zone air sampling results for the kettle operator were calculated and are shown in Table 14 The NTP standardized mean

concentration of TP for the kettle operator was 0 00012 mg/m^{3}lb (SD = 0 00006 mg/m^{3}lb) The NTP standardized mean BSF concentration for the kettle operator was 0 00007 mg/m^{3}lb (SD = 0 00005 mg/m^{3}lb) The NTP standardized mean total PAC concentration for the kettle operator was 0 01508 µg/m^{3}lb (SD = 0 01047 µg/m^{3}lb)

Table 14
Kettle Operator (IP-01) TP, BSF, and PAC Exposure Concentrations Adjusted to Normal Temperature and Pressure and Standardized by the Amount of Asphalt Used that Day

Sample Date	Sample Time (min)	NTP Standardized TP Conc (mg/m^{3}lb)	NTP Standardized BSF Conc (mg/m^{3}lb)	NTP Standardized 370 PAC Conc (µg/m^{3}lb)	NTP Standardized 400 PAC Conc (µg/m^{3}lb)	NTP Standardized Total PAC Conc (µg/m^{3}lb)
9/18/00	533	8 00e-05	4 00e-05	5 18e-03	1 29e-03	6 47e-03
9/19/00	544	1 70e-04	1 20e-04	2 05e-02	4 91e-03	2 54e-02
9/20/00	346	1 80e-04	1 00e-04	1 80e-02	4 75e-03	2 27e-02
9/21/00	627	6 00e-05	3 00e-05	4 56e-03	1 10e-03	5 66e-03

NTP = normal temperature and pressure
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}lb = milligrams per cubic meter of air per pound of asphalt used
µg/m^{3}lb = micrograms per cubic meter of air per pound of asphalt used
nm = nanometers
na = not available

Normalized and Standardized Area Sample Results For Samples Collected Around The Kettle

Area air samples collected at the four corners of the asphalt roofing kettle at breathing zone height were adjusted to NTP using the mean temperature and pressure for each day of sampling These adjusted results are shown in Table 12 Taking these data and dividing them by the amount of asphalt used each day, NTP standardized area results were calculated and are shown in Table 15 The NTP standardized mean TP concentration for area air samples collected around the kettle was 0 00008 mg/m^{3}lb (SD = 0 00010 mg/m^{3}lb) The NTP standardized mean BSF concentration for the samples

collected around the kettle was 0 00006 mg/m^{3}lb (SD = 0 00009 mg/m^{3}lb) The NTP standardized mean total PAC concentration for the samples collected around the kettle was 0 00890 µg/m^{3}lb (SD = 0 01139 µg/m^{3}lb)

Table 15
Area Air Sample Concentration Results For TP, BSF, and PAC Collected Around the Kettle Adjusted to Normal Temperature and Pressure and Standardized by the Amount of Asphalt used that Day

Sample Date	Sample Location Around Kettle	Sample Time (min)	NTP Standardized TP Conc (mg/m^{3}lb)	NTP Standardized BSF Conc (mg/m^{3}lb)	NTP Standardized 360 PAC Conc (µg/m^{3}lb)	NTP Standardized 400 PAC Conc (µg/m^{3}lb)	NTP Standardized Total PAC Conc (µg/m^{3}lb)
9/18/00	NE corner	511	3 00e-05	2 00e-05	1 95e-03	4 30e-04	2 38e-03
9/19/00	NE corner	544	6 00e-05	5 00e-05	4 04e-03	9 50e-04	4 99e-03
9/20/00	NE corner	348	1 60e-04	1 30e-04	1 81e-02	4 90e-03	2 30e-02
9/21/00	NE corner	613	2 00e-05	1 00e-05	2 90e-03	6 80e-04	3 58e-03
9/18/00	NW corner	511	1 00e-05	0 00e+00	5 20e-04	1 10e-04	6 30e-04
9/19/00	NW corner	544	2 00e-05	1 00e-05	9 30e-04	1 60e-04	1 09e-03
9/20/00	NW corner	348	3 00e-05	1 00e-05	1 17e-03	1 90e-04	1 36e-03
9/21/00	NW corner	613	2 00e-05	1 00e-05	1 63e-03	3 90e-04	2 03e-03
9/18/00	SE corner	511	8 00e-05	7 00e-05	8 00e-05	9 00e-05	1 70e-04
9/19/00	SE corner	544	6 00e-05	5 00e-05	7 84e-03	1 90e-03	9 74e-03
9/20/00	SE corner	348	4 00e-04	3 50e-04	3 27e-02	7 26e-03	4 00e-02
9/21/00	SE corner	613	1 50e-04	1 10e-04	2 08e-02	5 21e-03	2 60e-02
9/18/00	SW corner	511	3 00e-05	2 00e-05	2 26e-03	5 70e-04	2 83e-03
9/19/00	SW corner	544	6 00e-05	5 00e-05	8 08e-03	1 92e-03	9 99e-03
9/20/00	SW corner	348	1 40e-04	9 00e-05	9 56e-03	2 75e-03	1 23e-02
9/21/00	SW corner	613	2 00e-05	1 00e-05	1 88e-03	5 00e-04	2 38e-03

NTP = normal temperature and pressure
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^3lb = milligrams per cubic meter of air per pound of asphalt used
$\mu g/m^3lb$ = micrograms per cubic meter of air per pound of asphalt used
nm = nanometers

Normalized and Standardized Roof Level Worker Sample Results

Personal breathing zone air samples collected on the roof level workers were adjusted to NTP These sample results are shown in Table 13 Taking these results and dividing them by the amount of asphalt used each day, NTP standardized results were calculated for the roof level workers and are shown in Table 16

The NTP standardized mean TP concentration for all roof-level workers was 0 00013 mg/m^3lb (SD = 0 00013 mg/m^3lb) The NTP mean BSF concentration for all roof-level workers was 0 00010 mg/m^3lb (SD = 0 00011 mg/m^3lb) The NTP mean total PAC concentration for all roof-level workers was 0 01821 $\mu g/m^3lb$ (SD = 0 01760 $\mu g/m^3lb$)

Table 16
Roof-Level Worker TP, BSF, and PAC Exposure Concentrations Adjusted to Normal Temperature and Pressure and Standardized by the Amount of Asphalt Used that Day

Sample Date	Worker ID Number	Sample Time (min)	NTP Standardized TP Conc (mg/m^3lb)	NTP Standardized BSF Conc (mg/m^3lb)	NTP Standardized 370 PAC Conc ($\mu g/m^3lb$)	NTP Standardized 400 PAC Conc ($\mu g/m^3lb$)	NTP Standardized Total PAC Conc ($\mu g/m^3lb$)
9/18/0000	IP-02	215	4 70e-04	3 90e-04	4 44e-02	1 01e-02	5 45e-02
9/19/00	IP-02	238	5 00e-05	3 00e-05	5 22e-03	1 11e-03	6 33e-03
9/21/00	IP-02	274	2 60e-04	1 90e-04	3 75e-02	9 60e-03	4 71e-02
9/18/00	IP-03	219	1 60e-04	1 40e-04	1 73e-02	4 09e-03	2 14e-02
9/19/00	IP-03	239	1 90e-04	1 40e-04	2 48e-02	5 86e-03	3 06e-02
9/20/00	IP-03	252	4 00e-05	1 00e-05	4 05e-03	8 80e-04	4 93e-03
9/21/00	IP-03	266	7 00e-05	4 00e-05	6 96e-03	1 76e-03	8 73e-03

9/18/00	IP-04	127	1 30e-04	1 10e-04	1 40e-02	3 21e-03	1 72e-02
9/19/00	IP-04	233	7 00e-05	3 00e-05	5 40e-03	1 18e-03	6 58e-03
9/20/00	IP-04	348	2 00e-05	1 00e-05	3 09e-03	3 50e-04	3 44e-03
9/21/00	IP-04	267	1 00e-05	1 00e-05	9 00e-05	6 00e-05	1 50e-04
9/20/00	IP-05	252	1 00e-04	5 00e-05	1 41e-02	3 43e-03	1 75e-02

NTP = normal temperature and pressure
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^3lb = milligrams per cubic meter of air per pound of asphalt used
$\mu g/m^3lb$ = micrograms per cubic meter of air per pound of asphalt used
nm = nanometers

DISCUSSION

Only TruLo™ low fuming roofing asphalt was used during this survey, therefore, comparisons between conventional and low fuming asphalt exposure results were not possible Comparing these results to data collected at a previously surveyed roofing site, the Toledo Correctional Institute, where low fuming asphalt was also used, the results were very similar The kettle operator (GP-01) at the Toledo roofing site had mean NTP TP, BSF, and total PAC concentrations of 1 30 mg/m^3, 0 21 mg/m^3, and 61 $\mu g/m^3$, respectively The kettle operator (IP-01) for this site had mean NTP TP, BSF, and total PAC concentrations of 0 54 mg/m^3, 0 34 mg/m^3, 66 $\mu g/m^3$, respectively Aside from the mean NTP TP results, the results for the two kettle operators were very similar The area air sample results for the samples collected around the kettle at the Toledo site when low fuming asphalt was used for mean NTP TP, BSF, and total PAC were 0 43 mg/m^3, 0 37 mg/m^3, and 42 $\mu g/m^3$, respectively The area sample results for the samples collected around the kettle at this site for mean NTP TP, BSF, and total PAC were 0 30 mg/m^3, 0 22 mg/m^3, and 34 $\mu g/m^3$, respectively Comparing samples collected around the kettle from the two sites showed very similar results for mean NTP TP, BSF, and total PAC The mean NTP TP, BSF, and total PAC concentration results for the roof level workers at the Toledo site when low fuming asphalt was used were 0 38 mg/m^3, 0 23 mg/m^3, and 51 $\mu g/m^3$, respectively The mean NTP TP, BSF, and total PAC concentration results for the roof level workers at this site were 0 72 mg/m^3, 0 54 mg/m^3, and 98 $\mu g/m^3$, respectively The results for the roof level workers at this site were all higher in concentration than those from the Toledo site

CONCLUSIONS

During this survey, samples were collected for four days during which low fuming asphalt was used Although it was not possible to compare these results with those for conventional asphalt at this site, the sample results indicate that the exposures when low fuming asphalt was used are very similar to those measured at a previously surveyed roofing site where low fuming asphalt was used [37]

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