SURVEY REPORT

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

AT

Carroll Bell Elementary School
San Antonio, Texas

REPORT WRITTEN BY
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FACILITIES SURVEYED	Carroll Bell Elementary School 2717 Pleasanton Rd San Antonio, Texas
SIC CODE	1761
SURVEY DATES	December 14, 17, and 18, 2001
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SUMMARY

On December 14, 17, and 18, 2001, a field survey was conducted at a construction site where a built up asphalt roof was being installed on a new wing being added to Carroll Bell Elementary School in San Antonio, Texas The survey was conducted to evaluate the effectiveness of using an afterburner system with a safety loading door on an asphalt kettle to reduce worker exposure to asphalt fumes

Personal breathing zone and area air samples were collected and analyzed for total particulate (TP), benzene soluble fraction (BSF) of the TP, and total polycyclic aromatic compounds (PAC) These three analyses were chosen to represent indices of exposure to asphalt fumes Air samples were collected with the afterburner on and the kettle lid closed The afterburner system could not be turned off at this site due to the close proximity of the construction site to the rest of the school, therefore no samples were collected with the afterburner system off Air samples were collected on the kettle operator and two roof level workers, area air samples were collected around the four corners of the kettle

Because only one control condition, afterburner on and kettle lid closed, was used, it was not possible to make comparisons to show the effectiveness of using an afterburner system with a safety loading door to reduce worker exposure to asphalt fumes during the installation of a built up asphalt roof The results are simply reported as collected and will be added to results from other survey sites

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), a federal agency located in the Centers for Disease Control and Prevention (CDC) under the Department of Health and Human Services, was established by the Occupational Safety and Health Act of 1970 This legislation mandated NIOSH to conduct research and education programs separate from the standard setting and enforcement functions conducted by the Occupational Safety and Health Administration (OSHA) in the Department of Labor An important area of NIOSH research deals with methods for controlling occupational exposure to potential biological, chemical, and physical hazards

The Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology has been given the lead within NIOSH to study the engineering aspects relevant to the control of hazards in the workplace Since 1976, EPHB has assessed control technology found within selected industries or used for common industrial processes EPHB has also designed new control systems where current industry control technology was insufficient The objective of these studies was to document and evaluate effective control techniques (e g , isolation or the use of local ventilation) that minimized the risk of potential health hazards and created an awareness of the usefulness and availability of effective hazard control measures

One industry identified for EPHB control studies is asphalt roofing Epidemiologic studies of roofers have demonstrated an excess of lung, bladder, renal, brain, liver, and digestive system cancers among roofers or other occupations with the potential for exposure to asphalt [1-16] It is unclear to what extent these findings may be attributable to asphalt fume exposure Roofers in the past have also been exposed to coal tar and asbestos which are known carcinogens

Based on the epidemiological data, researchers from EPHB developed a project to evaluate engineering controls in the asphalt roofing industry Due to the high asphalt temperatures used in the roofing process, roofing kettle operators may be at higher risk of asphalt fume exposure than workers in any other industry or trade using asphalt 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 are obtained The asphalt temperature in the kettle is maintained somewhat higher than the EVT of the asphalt The actual maintenance temperature of the kettle will vary according to outdoor temperature, length of hot pipe, asphalt usage rate, pump flow rate, and type of receiving vessels on the roof Table 1 shows the EVT and other thermal properties for four types of asphalt The flashpoint (FP) is the temperature at which the asphalt may burst into flame The maximum heating temperature is 25 °F less than the FP and should never be exceeded The type of asphalt used in an application is determined by, among other things, the slope of the roof being built

Table 1 Thermal Properties of Various Types of Asphalt				
Type Number	Kind of Asphalt	Maximum Heating Temperature (°F)	Flash-point Temperature (°F)	EVT ±25 °F
Type I	Dead Level	475	525	375
Type II	Flat	500	550	400
Type III	Steep	525	575	425
Type IV	Special	525	575	425

HEALTH EFFECTS/OCCUPATIONAL EXPOSURE CRITERIA

There are three primary sources used in the United States for environmental evaluation criteria NIOSH Recommended Exposure Limits (RELs), the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and the U S Department of Labor OSHA Permissible Exposure Limits (PELs) OSHA has specific PELs regulating the construction industry [21] The OSHA PELs are the only legally enforceable exposure criteria among those listed, and during their development, OSHA must consider the feasibility of controlling exposures in addition to the related health effects In contrast, NIOSH RELs are based primarily on concerns relating to health effects The ACGIH TLVs refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be exposed, day after day, without adverse health effects The ACGIH is a private professional society and states that the TLVs are only guidelines

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

In 1977, NIOSH established an REL of 5 0 mg/m^3 (total particulate) measured as a 15-minute ceiling limit for asphalt fumes to protect against irritation of the serous membrane of the conjunctiva and the mucous membrane of the respiratory tract In 1988, NIOSH (in testimony to the Department of Labor) recommended that, based on the OSHA cancer policy,[25] asphalt fumes should be considered a potential occupational carcinogen [26] This recommendation was based on information presented in the Niemeier et al study [27] This NIOSH conclusion is based on the collective evidence found in available health effects and exposure data [28]

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

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

In the roofing industry, exposure to asphalt fumes and other related exposures is well documented and studies still continue Several studies have identified increased polycyclic aromatic compounds (PACs) exposure in kettle operators versus other categories of roofers [27] Due to the nature of the kettle operator's job, this appears to be an obvious conclusion, however, few controls have been utilized to minimize these exposures

ENGINEERING CONTROLS

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

STUDY BACKGROUND

A survey was conducted December 14, 17, and 18, 2001, at Carroll Bell Elementary School in San Antonio, Texas with the Mahone Roofing and Sheet Metal Company A built-up roof (BUR) was being applied to a new wing being added to an existing school building The engineering control used at the high school was a Reeves afterburner system Other existing engineering controls for this industry are being evaluated in other surveys A final report will summarize each of the engineering controls evaluated in the surveys

SITE DESCRIPTION AND WORK ACTIVITY

Carroll Bell Elementary School is a large multiple wing school that had a wing addition under construction when the survey was conducted The roof being applied consisted of one layer of polyisocyanurate installation board, a layer of Perlite board, 2-plies of black fiber glass felt paper, and a mineral surface fiber glass cap sheet Shown in Table 2 is the amount of asphalt used each day of the survey

Table 2 Amount of Asphalt Used Each Day Carroll Bell Elementary School

Date	Amount of Asphalt Used (pounds)
12/14/2001	3000
12/17/2001	3700
12/18/2001	3000

The roofers began work at 8 00 a m each day At that time, the kettle operator loaded asphalt into a 650 gallon kettle manufactured by Reeves and equipped with two afterburners and lit the propane burners to bring the asphalt up to the correct temperature The kettle was located at ground level in the middle of the construction area where the new wing was being added During the three days that the survey was conducted, the roofers only worked on this wing installing BUR

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 the afterburner operating and the safety loading kettle lid opened and closed However, in this particular study, all samples were taken with the afterburner on and the kettle lid closed Personal breathing zone and area air samples were collected and analyzed for total particulate (TP) and benzene soluble fraction (BSF) of the total particulate using NIOSH Manual of Analytical Methods (NMAM) Method 5042, and NMAM Method 5800 was used to analyze the samples for PACs [36] The temperature of the hot asphalt was recorded periodically with an electronic thermocouple and compared to the temperature gauge permanently mounted on the kettle

Air Sampling

The personal breathing zone and area air sampling consisted of two sampling trains per worker or area One sampling train was used to collect TP and BSF, and the other train was used to collect total PACs Both sampling trains' pumps were calibrated to an air flow rate of 2 liters per minute (Lpm) Personal breathing zone air samples were collected on the kettle operator and three roof level workers Area air samples were collected at each of the four corners around the kettle The area air samplers were placed in tripods, and the sampling media were positioned to breathing zone height (approximately 60 inches above the ground)

Kettle Temperature

The kettle was equipped with a permanently mounted temperature gauge This gauge reading is used by the kettle operator to monitor and maintain 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 three days of sampling at Carroll Bell Elementary School are the mean kettle temperature measurements along with the mean kettle gauge temperature measurements

Table 3 Summary of Kettle Temperature Data Carroll Bell Elementary School					
Date	Number of Measurements	Mean Kettle Temperature (°F)	Minimum Kettle Temperature (°F)	Maximum Kettle Temperature (°F)	Mean Gauge Kettle Temperature (°F)
12/14/2001	3	498	490	503	434
12/17/2001	5	513	498	534	431
12/18/2001	6	518	471	539	441

RESULTS

Kettle Operator Personal Breathing Zone Sample Results

Personal breathing zone air samples collected on the kettle operator at the elementary school site were analyzed for TP, BSF, and total PAC Samples were collected for three days During the three days of sampling, the afterburner was on, and the kettle lid was kept closed except when asphalt was added

Table 4 Kettle Operators' Exposure Concentrations Carroll Bell Elementary School								
Sample Date	Worker ID Number	Sample Time (min)	TP Conc (mg/m³)	BSF Conc (mg/m³)	370 PAC Conc (µg/m³)	400 PAC Conc (µg/m³)	Total PAC Conc (µg/m³)	Kettle Conditions
12/14/2001	NP-11	389	1 19	0 58	64 9	15 6	80 5	afterburner on, lid closed
12/17/2001	NP-14	424	0 45	0 19	1 69	3 58	5 26	afterburner on, lid closed
12/18/2001	NP-14	409	0 60	0 26	1 72	9 48	11 2	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/m³ = milligrams per cubic meter of air
µg/m³ = micrograms per cubic meter of air
nm = nanometers
na = not available

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 analyzed for TP, BSF, and PAC These results are shown in Table 5

Table 5 Area Air Sample Concentration Results For Samples Collected Around the Kettle Carroll Bell Elementary School

Sample Date	Sample Location Around Kettle	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)	Kettle Conditions
12/14/2001	NE corner	406	0 20	0 05	20 0	3 76	23 8	afterburner on, lid closed
12/14/2001	NW corner	406	0 30	0 08	7 34	1 24	8 58	afterburner on, lid closed
12/14/2001	SE corner	406	0 22	0 10	34 2	5 01	39 3	afterburner on, lid closed
12/14/2001	SW corner	406	0 70	0 48	121	24 0	145	afterburner on, lid closed
12/17/2001	NE corner	441	0 28	0 18	13 2	15 6	28 9	afterburner on, lid closed
12/17/2001	NW corner	441	0 16	0 03	1 64	0 16	1 80	afterburner on, lid closed
12/17/2001	SE corner	441	0 43	0 30	1 59	5 83	7 41	afterburner on, lid closed
12/17/2001	SW corner	441	1 13	0 16	86 6	22 6	109	afterburner on, lid closed
12/18/2001	NE corner	420	1 10	0 65	108	24 5	132	afterburner on, lid closed
12/18/2001	NW corner	420	0 43	0 17	1 75	8 17	9 92	afterburner on, lid closed
12/18/2001	SE corner	420	0 31	0 08	10 3	5 01	15 3	afterburner on, lid closed
12/18/2001	SW corner	420	0 57	0 10	1 72	5 59	7 31	afterburner on, lid closed

Roof Level Worker Personal Breathing Zone Sample Results

Personal breathing zone air samples were collected on the roof level workers Two roof level workers were sampled for TP, BSF, and total PAC for four days One of the workers was mopping and the other was lugging asphalt These sample results are shown in Table 6

Table 6 Roof-Level Workers' Exposure Concentrations Carroll Bell Elementary School								
Sample Date	Worker 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)	Kettle Conditions
12/14/2001	NP-11	287	1.27	0.49	103	17.0	120	afterburner on, lid closed
12/17/2001	NP-11	302	0.81	0.66	2.41	0.24	2.65	afterburner on, lid closed
12/18/2001	NP-11	310	0.91	0.84	143	24.2	168	afterburner on, lid closed
12/14/2001	NP-12	287	1.22	0.87	151	24.9	176	afterburner on, lid closed
12/17/2001	NP-13	302	0.63	0.27	35.4	6.23	41.6	afterburner on, lid closed
12/17/2001	NP-13	309	1.25	1.17	200	40.0	240	afterburner on, lid closed

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 7.

Table 7. Mean Ambient Air Temperature and Pressure Measurements Carroll Bell Elementary School			
Date	Number of Measurements	Mean Ambient Air Temperature (°F)	Mean Barometric Pressure (in Hg)
12/14/2001	11	60.1	29.41
12/17/2001	11	66.7	29.49
12/18/2001	12	62.2	29.37

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 8 for the kettle operators, Table 9 for the area air samples collected around the kettle, and Table 10 for the roof level workers. By adjusting to NTP, data from different sites can be more readily compared.

Table 8 Kettle Operators' NTP Exposure Concentrations Carroll Bell Elementary School					
Sample Date	Worker ID Number	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc (μg/m^3)	Kettle Conditions
12/14/2001	NP-11	1 18	0 57	84 4	afterburner on, lid closed
12/17/2001	NP-14	0 45	0 19	4 65	afterburner on, lid closed
12/18/2001	NP-14	0 56	0 26	9 19	afterburner on, lid closed

Table 9 NTP Area Air Sample Concentration Results For Samples Collected Around the Kettle Carroll Bell Elementary School						
Sample Date	Sample Location Around Kettle	Sample Time (min)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc (μg/m^3)	Kettle Conditions
12/14/2001	NE corner	406	0 20	0 05	18 9	afterburner on, lid closed
12/14/2001	NW corner	406	0 30	0 08	6 80	afterburner on, lid closed
12/14/2001	SE corner	406	0 22	0 10	31 1	afterburner on, lid closed
12/14/2001	SW corner	406	0 69	0 47	115	afterburner on, lid closed
12/17/2001	NE corner	441	0 28	0 18	25 5	afterburner on, lid closed
12/17/2001	NW corner	441	0 16	0 03	1 59	afterburner on, lid closed
12/17/2001	SE corner	441	0 43	0 30	6 55	afterburner on, lid closed
12/17/2001	SW corner	441	1 13	0 16	96 4	afterburner on, lid closed
12/18/2001	NE corner	420	1 09	0 65	109	afterburner on, lid closed
12/18/2001	NW corner	420	0 42	0 16	8 14	afterburner on, lid closed
12/18/2001	SE corner	420	0 31	0 08	12 5	afterburner on, lid closed
12/18/2001	SW corner	420	0 56	0 10	6 00	afterburner on, lid closed

Table 10 Roof-Level Workers' NTP Exposure Concentrations Carroll Bell Elementary School

Sample Date	Worker ID Number	Sample Time (min)	NTP TP Conc (mg/m^3)	NTP BSF Conc (mg/m^3)	NTP Total PAC Conc ($\mu g/m^3$)	Kettle Conditions
12/14/2001	NP-11	287	1 25	0 48	95 4	afterburner on, lid closed
12/17/2001	NP-11	302	0 81	0 66	2 34	afterburner on, lid closed
12/18/2001	NP-11	310	0 90	0 83	138	afterburner on, lid closed
12/14/2001	NP-12	287	1 20	0 85	140	afterburner on, lid closed
12/17/2001	NP-13	302	0 62	0 27	36 8	afterburner on, lid closed
12/18/2001	NP-13	309	1 24	1 15	197	afterburner on, lid closed

DISCUSSION AND CONCLUSIONS

In this survey, measurements were taken of TP, BSF, and total PAC on the kettle operator, roof level worker, and in the area around the asphalt kettle All measurements were taken with the afterburner on and the kettle lid closed Because only one control condition was used, it was not possible to make a comparison to determine if the afterburner control was effective in reducing worker exposure to asphalt fumes However, the results from this survey will be used in conjunction with the results of other surveys of work sites that had an afterburner system on the asphalt kettle

To be consistent with other surveys, the results collected at this site were analyzed in two ways The results were first reported as they were collected Then, the results were adjusted to normal temperature and pressure (77° F and 29 29 in Hg) to account for any differences that may be due to the weather conditions at the time the measurements were taken This allows results from different sites to be compared

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