IN-DEPTH SURVEY REPORT:

CONTROL TECHNOLOGY FOR CONTROLLING WORKER EXPOSURE TO ASPHALT FUMES FROM ROOFING KETTLES: KETTLE OPERATED USING THE FRS-6000™ FILTRATION UNIT

AT

Dana Corporation
Columbus, Ohio

REPORT WRITTEN BY
Charles S Hayden II

REPORT DATE
October 7, 1998

REPORT NO
ECTB 231-11a

U S DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
4676 Columbia Parkway, Mailstop R-5
Cincinnati, Ohio 45226

FACILITY SURVEYED	Dana Corporation P O Box 278 Hilliard, Ohio 43026
SIC CODE	1761
SURVEY DATES	March 23-27, 1998
SURVEY CONDUCTED BY	Charles S Hayden II Dave Marlow Ova Johnston
FACILITY REPRESENTATIVE	Paul Brosher, Facilities Manager
CONTRACTOR	Casey Bechtel, President Harold J Becker Company Inc 3946 Indian Ripple Road P O Box 340970 Dayton, Ohio 45434-0970 937-426-4951
EMPLOYEE REPRESENTATIVE	No Union
ANALYTICAL WORK PERFORMED BY	DataChem Laboratories 960 West LeVoy Drive Salt Lake City, Utah 84123-2547 Chuck Neumeister NIOSH, CDC Division of Physical Sciences and Engineering 4676 Columbia Parkway Cincinnati, Ohio 45226
MANUSCRIPT PREPARED BY	Bernice L Clark

DISCLAIMER

Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), a federal agency located in the Centers for Disease Control and Prevention 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 Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects relevant to the control of hazards in the workplace Since 1976, the ECTB has assessed control technology found within selected industries or used for common industrial processes The ECTB has also designed new control systems where current industry control technology was insufficient The objective of these studies has been to document and evaluate effective control techniques (e g , isolation or the use of local ventilation) that minimize risk of potential health hazards and to create an awareness of the usefulness and availability of effective hazard control measures

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

As a result of the epidemiological data, researchers from ECTB developed a project to evaluate engineering controls in the asphalt roofing industry Due to high asphalt temperatures used in the roofing process, roofing kettle operators may be at a higher risk of asphalt fume exposure than any other industry or trade worker This project evaluates existing engineering controls of 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 percent of those workers were covered under a collective bargaining agreement These workers worked primarily for small contractors who generally lack detailed occupational safety and health programs or a designated occupational safety and health expert -- about 90 percent of roofing contractors have fewer than 20 employees Studying ways to reduce exposure to these construction workers addresses 10 2 of Healthy People 2000 Objectives, NIOSH National Occupational Research Agenda (NORA), and Occupational Safety and Health Administration (OSHA) Priorities.[17-19]

While this project concerned itself primarily with the reduction of asphalt fume exposure to kettle operators, parallel studies in cooperation with the ECTB study provide an in-depth examination of asphalt fume exposures to roofing workers on the roof during hot asphalt application These studies include 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 roofing asphalt at the correct temperature for application on the roof during construction of built-up roofs (BUR) BURs are layers or plys of 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 also 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 Asphalt temperature is controlled by throttling the propane supply to the burner(s) The throttle valves are 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 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 loading door designed to reduce worker exposure to asphalt fume 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 asphalt temperature in the kettle is maintained somewhat higher than the equiviscous temperature (EVT) of the respective asphalt type shown in Table 1 The 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 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 25°F less than the FP and should never be exceeded The type of asphalt used in an application is, among other things, determined according to the slope of the roof being built

Table 1

Maximum Heating Temperature, Flashpoint, and EVT of Various Types of Asphalt

Type No	Kind of Asphalt	Maximum Heating Temperature °F	Flash-point °F	EVT ± 25 °F
Type I	Dead Level	475	525	375
Type II	Flat	500	550	400
Type III & IV	Steep and Special	525	575	425

STUDY BACKGROUND

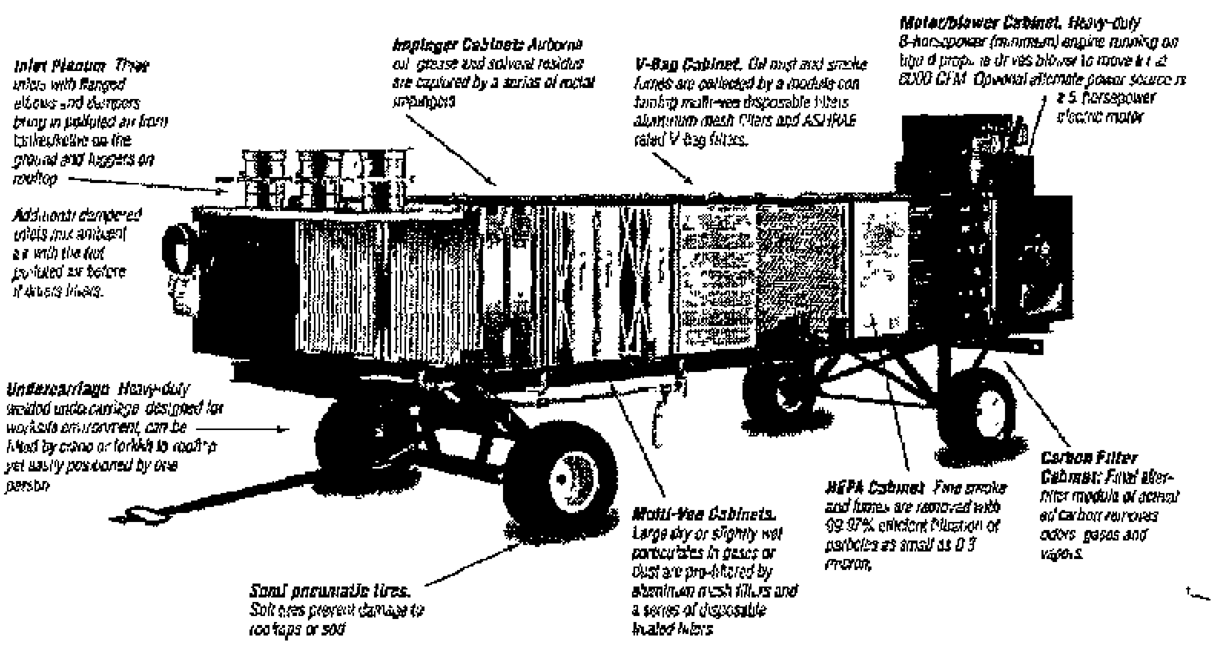
A survey was conducted on March 23-27, 1998, at the Dana Company in Columbus, Ohio, where a large section of coal tar pitch roof was removed and replaced with a 3-ply built-up asphalt roof The engineering controls used during this evaluation consisted of containment, ventilation, and filtration of asphalt fume from the kettle using the FRS-6000 filtration unit In addition to this survey, other existing engineering controls for this industry will be evaluated A final report will summarize the engineering controls evaluated from all of the surveys

The FRS-6000™ shown in Figure 1 is a portable filtration unit with an exhaust fan and duct system that connects the unit to the top of a modified roofing kettle The modification to the kettle includes a loading box/door and a 6-inch diameter flange adapter The loading box is a 32 inch x 22 inch x 22 inch steel box welded atop the kettle lid One side of the loading box has a hinged door The door opens and closes to load asphalt kegs The flange adapter is for the

6–inch diameter metal ventilation duct connecting the head space of the kettle to the filtration unit inlet The FRS-6000™ exhaust fan pulls asphalt fume from the head space of the kettle, through the metal duct, mixes the fume with ambient air to provide a dilution and cooling effect, and then directs the resulting mixture through a series of filters (bag, HEPA, and carbon) which trap the particulate and organic vapor The filtered exhaust is then released into the general environment The FRS-6000 has a rated flow rate of 6000 cubic feet per minute Exposure concerns related to cleaning and maintenance of the FRS-6000™ system were not evaluated in this study

Figure 1

FRS-6000 Fume Recovery System Filtration Unit



HEALTH EFFECTS/OCCUPATIONAL EXPOSURE CRITERIA

The primary sources of environmental evaluation criteria in the United States that can be used for the construction work environment are as follows (1) NIOSH Recommended Exposure Limits (RELs), (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and (3) the U S Department of Labor (OSHA) Permissible Exposure Limits (PELs) OSHA has specific PELs for regulating the construction industry (29 CFR Part 1926 55) The OSHA PELs are the only legally enforceable exposure criteria 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 the 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 repeatedly exposed, day after day, without adverse health effects The ACGIH is a private, professional society and states that the TLVs are only guidelines Currently, there is no specific OSHA PEL for asphalt fume As shown in Table 2, OSHA regulates asphalt fume as "Particulate Not Otherwise Classifiable" (PNOC) This was based on research which showed lower levels of carcinogenicity in petroleum based asphalt fume than in coal-tar pitch (CTP) fume The PNOC category has a higher PEL of 15 mg/m^3 total dust and 5 mg/m^3 respirable dust averaged over an 8-hour workday The ACGIH currently recommends a TLV of 5 mg/m^3 total particulate of asphalt fume and is proposing to adopt a 0 5 mg/m^3 (8-hr time weighted average [TWA]) as the cyclohexane-extractable inhalable particulate for asphalt fume NIOSH has an REL for asphalt fume of 5 mg/m^3 (15 minute TWA ceiling)

In the roofing industry, exposures to asphalt fume and other related exposures is well documented and studies still continue Several studies have identified increased polycyclic aromatic compounds (PAC) exposures to the kettle operators versus other categories of roofers[1,21,22] Due to the nature of the kettle operator's job, this appears to be an obvious conclusion, however, few controls have been utilized to minimize these exposures

SITE DESCRIPTION

Dana Company is a major manufacturer of bus and semi-truck axles During the one-week NIOSH survey, a 6,274 square foot section of roof at the Dana Company building was replaced by the Harold J Becker Company As shown in Table 2, a portion of this large section of built-up coal tar pitch roof was removed and replaced with a 3-ply built-up asphalt roof each day To prevent weather damage to the building interior, the roofing crew only removed as much of the old roof each day as they could replace by the end of that same work day Although the roofing crew worked each day, high winds and sleet prevented the crew from working full shifts on three of the five days of the NIOSH survey

Table 2

Area of Roof Replaced Each Day of the Survey

Day of Survey	Area of Roof Replaced Each Day (ft^2)
1	2116
2	1050
3	975
4	1125
5	1008

Typically, the roofers began work at 6:30 a.m. each day. At that time, the kettle operator loaded kegs of asphalt into a 660-gallon Garlock® kettle and lit the propane burners to begin bringing the asphalt up to temperature. The kettle was located at ground level near the inside corner of the L-shaped 30 foot high building. Concurrently, the old roof tear-off began. The eight man roofing crew on the roof cut out and pried up small squares of the old coal tar pitch roof. The squares were loaded into wheel barrels and transported to the edge of the building where they were dumped, through a trash chute, into a large refuse receptacle at ground level. The old roof was removed down to the existing deck, a corrugated aluminum sheet. During tear-off, the kettle operator at ground level assists the crew on the roof by adjusting the trash chute, changing out refuse receptacles, picking up loose debris, and ensuring the ground level area around the refuse receptacle remains clean and swept. At about 10:00 a.m., the installation of the new roof began. As in roof tear-off, during roof installation the crew has no clearly defined job description. They accomplish a variety of activities as the work situation dictates. These include: (1) carrying, cutting, and attaching insulation and fiber board to the existing deck; (2) carrying, rolling, and cutting felt, (3) mopping down hot asphalt, (3) ensuring the mop cart has a ready supply of hot asphalt, (4) completing finish work around air conditioning units, parapet walls, and drains

Two different kettle operators were used during the survey The first kettle operator worked the first day of the survey with the second operator replacing him the last four days of the survey The FRS-6000 filtration unit was not used the first day but was used on the preceding days of the survey

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 practicable, this was accomplished by evaluating the worker's exposure to asphalt fume particulate and PACs both with and without control implementation Personal air sampling, general area air sampling, and video exposure monitoring techniques were utilized Temperature of the hot asphalt was recorded periodically with an electronic thermocouple and compared to the temperature gauge permanently mounted on the kettle Control on and control off evaluations were conducted as the job site conditions permitted

Air Sampling

The personal and general area sampling consisted of two sampling trains per person or area One sampling train was designated for the analyses of total particulate (TP) and benzene soluble fraction (BSF) of TP The second sampling train was designated for the analyses of total PACs and pyrene Both sampling trains were calibrated to a flow rate of 2 liters per minute (lpm) Personal sampling (total six workers) was accomplished on the kettle operator, and five roof-level workers while area sampling (total four locations) was done near the building wall closest to the kettle, a short distance away from the kettle and building, inside the building, and on the roof The TP and BSF samples were collected and analyzed according to NIOSH Method 5042 (draft) [23] The total PAC samples were collected and analyzed using the NIOSH analytical method (draft) for total PACs, this sample was subsequently analyzed for pyrene using a method still in development Note the NIOSH analytical method (draft) for total PACs is a modification of NIOSH Method 5506

The roof being removed was a coal tar pitch built-up roof During the tear-off of this roof, coal tar pitch dust was generated To prevent coal tar pitch particulate from confounding TP and BSF samples, efforts were made to change out the sampling trains after the completion of the old roof tear-off and before the installation of the new asphalt built-up roof

On days one and two of the five-day survey, the weather permitted full work days with a definitive break between the old coal tar pitch roof tear-off and the installation of the new asphalt built-up roof During this break, the sampling trains were changed out to differentiate the TP and BSF airborne exposures to coal tar pitch dust and the TP and BSF airborne exposures to asphalt fume Due to high winds or precipitation there was no clear break between tear-off and installation on days 3, 4, and 5, and therefore, the samples are all-day samples for those respective days On all five survey days, the kettle operator remained at ground level and did not become directly involved in roof level activities such as the coal tar pitch tear-off

Video Exposure Monitoring

Real-time data overlaid onto corresponding video allows the researcher to visually associate elements of the kettle operator's work process with corresponding exposure levels This evaluation process is called video exposure monitoring Video exposure monitoring was used to determine kettle operator tasks which elevate the worker's air contaminant exposures

Real time exposure data of the kettle operator was gathered using the TVA-1000 (Foxboro Inc , Foxboro, MA) The TVA-1000 provides dual photo-ionization (PID) and flame ionization (FID) detection The TVA-1000 sampling point was positioned within the worker's breathing zone using a length of Tygon® tubing The PID and FID measures total VOCs (calibrated against a reference VOC)

Flow Rate Through the FRS-6000 Unit

A ten-point pitot traverse of the 6 inch diameter duct connecting the kettle to the FRS-6000 filtration unit measured airflow rate from the kettle[24] A Neotronics (Gainsville, GA) Model MP20 electronic digital micro manometer provided a digital readout of velocity pressure for the pitot traverse A TSI, Inc (St Paul, MN) Model 8370 balometer flow hood measured the airflow rate of ambient air being mixed with the kettle exhaust upstream of the filtration unit The balometer also measured total airflow rate from the filtration unit exhaust

Kettle Temperature

The kettle is equipped with a permanently mounted temperature gage This gage reading 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

RESULTS AND DISCUSSION

Kettle Operator Sample Results

The five-day average of TP, BSF, and PAC exposures to the kettle operators were 1 58 mg/m^3, 1 08 mg/m^3, and 186 μg/m^3 respectively The data shown in Table 3, days 1 and 2, indicate the lowest level of airborne TP, BSF, and PAC airborne exposure to the kettle operator occurs in the a m During this period, the kettle operator is heating the asphalt for p m use and monitoring the kettle temperature He is not opening a hot kettle to load asphalt or to skim Taking into consideration the limited amount of data, the p m and day exposure data demonstrate a three-fold increase in TP and BSF exposure and a two-fold increase in PAC exposures over the a m exposure data During this period, hot asphalt is being applied on the roof and the kettle operator is periodically opening the kettle lid to load solid asphalt kegs to maintain a supply of hot asphalt in the kettle He is also skimming the hot asphalt surface, increasing his residence time in the asphalt fume coming from the kettle The kettle temperature was operated at 550-575°F throughout the week There was good correlation between the microprocessor/thermocouple and the permanently mounted temperature gage There was little noticeable difference in exposures to the kettle operator between the control off day and the control on days

In Table 3, while only a m and p m samples were taken for the first two days of the survey, the results are combined to give full day results (rows 5 and 6 of the data) for comparison to the full day only samples from days 3-5 (rows 7-9)

The low PAC exposure for the kettle operator on the third day of the survey is low in comparison to the other survey days The reason for this is undetermined For kettle operator, area, and roof level worker exposure data, there is significant positive correlation between TP, BSF, and PAC exposures (96% for TP-BSF, 77% for BSF-PAC, and 70% for TP-PAC)

Table 3

Kettle Operator TP, BSF, and PAC Exposure Levels

Kettle Operator	Day	AM/PM /Day	Sample Time (hr)	Sample Volume (liters)	TP mg/m^3	BSF mg/m^3	PACs μg/m^3	FRS-6000 Control ON/OFF
1	1	am	4 78	574	0 76	0 41	99	off
1	1	pm	1 85	222	1 98	1 57	361	off
1	1	day	6 63	796	1 11	0 73	185	off
2	2	am	3 68	442	0 55	0 47	102	on
2	2	pm	3 78	454	1 01	0 64	125	on
2	2	day	7 46	896	0 79	0 56	114	on
2	3	day	6 23	748	1 83	1 26	27	on
2	4	day	3 55	426	2 22	1 19	210	on
2	5	day	1 90	398	2 72	2 03	381	on

Kettle Area and Building Interior Sample Results

The five-day average of TP, BSF, and PAC levels in the area and building samples 0 34 mg/m^3, 0 12 mg/m^3, and 22 μg/m^3 respectively The area sample data shown in Table 4 indicates there may be a slight reduction in TP, BSF, and PAC level in the general environment ("area wall" by a wall 10 feet from the kettle) and by the FRS-6000 filtration unit ("area frs") The area samples taken in the building show very little, if any, migration of asphalt fume into the building interior at any time during the survey The building PAC levels averaged over the five-day period were 17 times lower than the area samples taken outside near the kettle and filtration unit (2 [inside] to 34 [outside] $\mu g/m^3$)

Table 4

Area Sample Results Showing TP, BSF, and PAC Levels at Various Locations

Location	Day	AM/PM /Day	Sample Time (hr)	Sample Volume (liters)	TP mg/m^3	BSF mg/m^3	PACs $\mu g/m^3$	FRS-6000 Control ON/OFF
area wall	1	day	7 22	866	0 73	0 32	47	off
area wall	3	day	5 53	664	0 28	0 08	24	on
area wall	4	day	5 72	686	0 61	0 15	36	on
area wall	5	day	6 02	722	0 61	0 22	77	on
area frs	1	day	7 22	866	0 25	0 15	36	off
area frs	3	day	5 37	644	0 03	0 04	4	on
area frs	4	day	5 53	664	0 36	0 14	15	on
area frs	5	day	5 43	652	0 30	0 14	33	on
building	1	day	7 75	930	0 21	0 05	3	off
building	2	day	7 97	956	0 25	0 06	4	on
building	3	day	6 12	734	0 32	0 14	1	on
building	4	day	5 67	680	0 28	0 06	0	on
building	5	day	6 17	740	0 19	0 04	1	on

Roof Level Crew Sample Results

The five-day overall average of TP, BSF, and PAC exposures to the roof level crew were 0 77 mg/m^3, 0 37 mg/m^3, and 75 $\mu g/m^3$ respectively As shown in Table 5, and presented here for comparison to the kettle operator and area exposures, the five-day average of TP, BSF, and PAC levels in the a m samples are 0 86 mg/m^3, 0 32 mg/m^3, and 43 $\mu g/m^3$ respectively The five- day average of TP, BSF, and PAC levels in the p m samples are 1 0 mg/m^3, 0 61 mg/m^3, and 123 $\mu g/m^3$ respectively The five-day average of TP, BSF, and PAC levels for the all day samples are 0 5 mg/m^3, 0 22 mg/m^3, and 65 $\mu g/m^3$ respectively While TP exposures during the a m are approximately equal to TP exposures in the p m , the BSF exposures increase two-fold in the p m , and the PAC exposures to the roof level crew increase three-fold in the p m

Table 5

Roof-level Worker TP, BSF, and PAC Exposure Levels

Day	Worker #	AM/PM /Day	Sample Time (hr)	Sample Volume (liters)	TP mg/m^3	BSF mg/m^3	PACs $\mu g/m^3$
1	1	am	5 00	600	0 53	0 14	54
1	1	pm	2 20	264	0 75	0 42	130
1	3	am	5 22	626	1 06	0 15	67
1	3	pm	2 10	252	0 96	0 50	133
1	4	am	5 12	614	0 99	0 16	67
1	4	pm	2 18	262	1 61	1 31	278
1	5	am	5 18	622	0 16	0 07	44
1	5	pm	0 97	116	0 61	0 38	72
1	6	am	3 88	466	3 34	1 87	60
2	1	am	3 30	396	0 57	0 17	26
2	1	pm	4 05	486	0 56	0 28	54
2	3	am	3 32	398	0 29	0 07	31
2	3	pm	4 12	494	0 95	0 40	137
2	4	am	3 28	394	0 30	0 23	28
2	4	pm	4 08	490	1 13	0 89	9
2	5	am	3 53	424	0 39	0 11	29
2	5	pm	3 97	476	1 74	1 08	234
2	6	am	0 97	116	0 97	0 22	23
2	6	pm	3 20	384	0 69	0 26	58

3	1	day	6 03	724	0 41	0 14	58
3	3	day	5 98	718	0 62	0 24	124
3	4	day	6 10	732	0 46	0 15	35
3	5	day	6 03	724	0 44	0 17	49
4	3	day	5 28	634	0 57	0 16	9
4	4	day	5 10	612	0 47	0,12	5
4	5	day	1 82	218	0 20	0 01	52
5	1	am	4 43	532	0 37	0 09	15
5	1	pm	1 28	154	1 16	0 99	290
5	2	am	1 20	144	0 33	0 26	54
5	2	pm	4 45	534	0 44	0 06	21

FRS-6000 Flow Rates

Air flow rates of air being pulled from the head space of the kettle with the hinged loading door closed was 170 cfm (a 460 ft/min face velocity through cracks around the lid and door) With the hinged door on the kettle lid open, the measured air flow rate was 700 cfm (a 140 ft/min face velocity through the door opening)

Video Exposure Monitoring

The video exposure monitoring of the kettle operator was unsuccessfully analyzed There was a high level of difficulty in synchronizing the data to be overlaid onto the video The difficulty in synchronization is due to the variable wind speeds found in the outdoor environment of the kettle While preliminary examination of the data and video indicate increased levels of asphalt fume exposure during loading and skimming when the FRS-6000 is on or off, the variable wind speeds cause inconsistent exposure measurements to be seen Therefore, no results are available from the video exposure monitoring

DISCUSSION

The kettle operator's asphalt fume exposure is significantly higher than both the area and roof level crew sampling results Work practices of the roof level crew such as trading off mopping the asphalt, laying felt, and doing finishing work could contribute to the overall lower levels of asphalt fume exposure experienced among them compared to the kettle operator The asphalt is hotter and the asphalt fume concentration is greater at the kettle than at roof level where the asphalt fume coming from the lugger, mop, or mop cart is lower due to having a cooler temperature The roof level crew can also take advantage of cross winds which were significantly greater than those found at ground level near the kettle The kettle operator's asphalt fume exposure appears to be intermittent Primarily due to loading and skimming of the kettle

Eight-hour samples were not possible during this survey However, assuming zero exposure for the time greater than actual sampling time up to eight hours, the 8-hr TWA TP exposure for the kettle operator and roof level workers was below the ACGIH TLV of 5 mg/m^3 The 8-hr TWA for TP was 15 to 100 times less than the OSHA PEL for particulate (PNOC) for all personnel sampled

Although asphalt fume exposure levels during maintenance of the FRS-6000 were not measured, the kettle operator's at this site agree that changing out the filters and wiping oils from the inside of the filtration unit far exceed any acute effects felt during normal operation of the kettle These acute effects included burning eyes, lungs, and mucous membranes The roofing crew foreman stated the FRS-6000 seems to remove the oils from the asphalt and the asphalt applies differently than when the FRS-6000 is not used The effect on the BUR quality or roof life due to the removal of oils from the hot asphalt was not within the scope of this study However, this affect may be important to the industry

Note the initial cost of the FRS-6000 filtration unit is between $50,000 and $70,000 depending on optional equipment The cost of replacing filters is about $3,300 per month Marketing data from National Tool Rental (Cleveland, OH) dated May 22, 1996, estimates initial and operating costs combine to give a hourly operations rate of between $45 00 and $51 00 for the FRS-6000

CONCLUSIONS

The five-day average of TP, BSF, and PAC exposures were 1 58 mg/m^3, 1 08 mg/m^3, and 186 μg/m^3 respectively to the kettle operators, 0 34 mg/m^3, 0 12 mg/m^3, and 22 μg/m^3 respectively in the area and building samples, and 0 77 mg/m^3, 0 37 mg/m^3, and 75 μg/m^3 respectively to the roof-level crew Whether the FRS-6000 filtration unit is used or not, these data show the kettle operator is being exposed to levels of asphalt fume higher than any other roofing worker This puts the kettle operator at the highest risk of adverse health effects

There was no significant correlation between the square foot of roof replaced (i e , asphalt used) in a day and the TP, BSF, and PAC exposures to the kettle operator for that day This is most likely due to the kettle operator loading fewer asphalt kegs (1 or 2) each time the kettle lid is opened during days where usage is low. During high asphalt use days, the kettle operator tends to load more kegs (3 or 4) each time the kettle is opened but does not necessarily open the door more often than on low usage days This observation is site specific and largely a function of the kettle size used and the kettle operator's work habits

Visible emissions were observed from the kettle during skimming and loading operations whether the filtration unit was on or off, while area samples (Table 4) taken a short distance away from the kettle indicated very low TP, BSF, and PAC concentrations over the sampling periods The FRS-6000 exhaust ventilation rate provided sufficient containment while the kettle lid was closed, but was insufficient to control asphalt fume during kettle loading or skimming Based on some initial real-time data, most of the kettle operator exposure comes when the kettle lid is opened Due to the small sample size, variability caused by the wind, and net affect of the control, the benefit of using the FRS-6000 filtration unit could not be statistically measured For example, the PAC concentration for the kettle operator was 185 $\mu g/m^3$ when the control was <u>not</u> used and ranged between 27-381 $\mu g/m^3$ when the control was used

While a reduction in exposure levels was not evident based on this studies data, the asphalt fume odor was noticeably diminished when the FRS-6000 was used This observation was made by a number of onsite researchers and the kettle operators

REFERENCES

1 CPWR [1993] Final report An investigation of health hazards on a new construction project Washington, DC The Center To Protect Workers' Rights

2 Partanen T, Boffetta P [1994] Cancer risk in asphalt workers and roofers review and meta-analysis of epidemiological studies Am J Ind Med *26* 721-747

3 Mommsen S, Aagard J, Sell A [1983] An epidemiological study of bladder cancer in a predominantly rural district Scand J Urol Nephrol *17*(3) 307-312

4 Risch HA, Burch JD, Miller AB, Hill GB, Steele R, Howe GR [1988] Occupational factors and the incidence of cancer of the bladder in Canada Br J Ind Med *45*(6) 361-367

5 Bonassi S, Merlo F, Pearce N, Puntoni R [1989] Bladder cancer and occupational exposure to polycyclic aromatic hydrocarbons Int J Cancer *44* 648-651

6 Jensen OM, Knudsen JB, McLaughlin JK, Sorensen BL [1988] The Copenhagen case-control study of renal, pelvis, and ureter cancer role of smoking and occupational exposures Int J Cancer *41*(4) 557-561

7 Hansen ES [1989] Cancer mortality in the asphalt industry a 10-year follow-up of an occupational cohort Br J Ind Med *46*(8) 582-585

8 Austin H, Delzell E, Grufferman S, Levine R, Morrison AS, Stolley PD, Cole P [1987] Case control study of hepatocellular carcinoma, occupation and chemical exposures J Occup Med *29*(8) 665-669

9 Siemiatycki J (editor) [1991] Risk factors for cancer in the workplace Boca Rotan, FL CRC Press

10 Menck HR, Henderson BE [1976] Occupational differences in rates of lung cancer J Occup Med *18* 797-801.

11 Engholm G, Englund A, Linder B [1991] Mortality and cancer incidence in Swedish road paving asphalt workers and roofers Health Environ *1* 62-68

12 Hrubec Z, Blair AE, Roget E, Vaught J [1992] Mortality risks by occupation among U S veterans of known smoking status (1954-1980) U S Department of Health and Human Services Public Health Service, National Institutes of Health (NIH), NIH Publication No 92-3407

13 Pukkala E [1995] Cancer risk by social class and occupation A survey of 109,000 cancer cases among Finns of working age New York Karger, p 53

14 Milham S [1997] Occupational mortality in Washington State 1950-1989 Order No 00913725 U S Department of Health and Human Services (DHHS), Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (NIOSH), Division of Surveillance, Hazard Evaluations, and Field Studies, Cincinnati, OH DHHS (NIOSH) Publication No 96-133

15 Zahm SH, Brownson RC, Chang JC, Davis JR [1989] Study of lung cancer histologic types, occupation, and smoking in Missouri Am J Ind Med *15* 565-578

16 Schoenberg JB, Sternhagen A, Mason TJ, Patterson J, Bill J, Altman R [1987] Occupation and lung cancer risk among New Jersey white males J Nat Can In

17 CDC [1990] Healthy People 2000 Objectives, 10 2 Reduce work related injuries Atlanta, GA U.S Department of Health and Human Services (DHHS), Public Health Service, Centers for Disease Control and Prevention

18 NIOSH [1996] Control Technology and Personal Protective Equipment NIOSH National Occupational Research Agenda (NORA) http //www cdc gov/niosh/nrppe html

19 OSHA [1995] OSHA Priority Planning Process Washington, D.C.

20 Herbert III RD, [1989] Roofing Design Criteria, Options, Selection Kingston, MA R.S. Means Company, Inc., pp 59-65

21 Bjorseth A, Becher G [1983] PAH in work atmospheres occurrence and determination Boca Raton, FL CRC Press, Inc., pp 129-131

22 NIOSH [1988] Hazard evaluation and technical assistance report Roofing construction Houston, TX Cincinnati, OH U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No HETA 83-210-1887

23 NIOSH [1984] Eller PM, ed NIOSH manual of analytical methods 3rd rev ed Cincinnati, OH U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No 84-100

24 American Conference of Governmental Industrial Hygienists (ACGIH) 1995 *Industrial Ventilation - A Manual of Recommended Practice, 22nd Edition* Cincinnati, Ohio ACGIH