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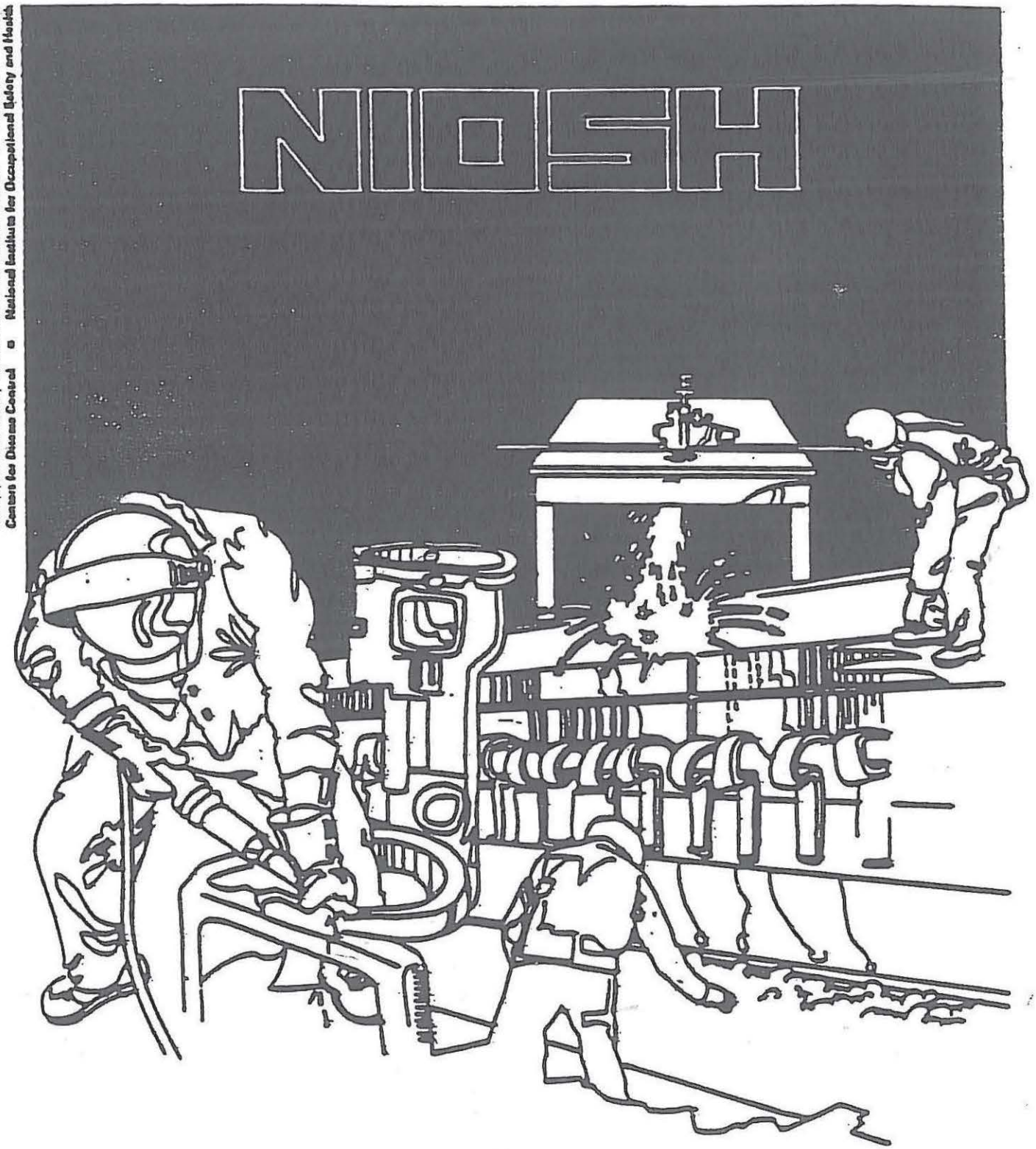

Health Hazard Evaluation Report

HETA 85-416-1742
ROOFING AND WATERPROOFING SITES
CHICAGO, ILLINOIS

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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ROOFING AND WATERPROOFING SITES
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I. SUMMARY

In June 1985, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Union of Roofers, Waterproofers, and Allied Workers to evaluate potential exposures of employees conducting roofing/waterproofing activities. Chicago, Illinois was selected as the location due to the variety of systems used and an established working relationship between the union and roofing/waterproofing contractors.

A NIOSH environmental team conducted field investigations of two roofing (ARC and Carlisle) and one waterproofing (WR Grace) site on August 27-28 and September 10-13, 1985. For each investigation air samples were collected for the chemicals the NIOSH investigators believed represented the principal exposure hazard. The exposures evaluated were organic solvent vapors, total particulates, and PNAs for the Carlisle system, PNAs and benzene solubles for the ARC system, and organic solvent vapors for the WR Grace system. Area air samples were also collected to be screened qualitatively for organic vapors.

Five organic solvents including toluene, xylene, hexane, acetone and heptane, were measured in at least some of the 22 partial-shift personal air samples collected at the Carlisle Roofing Site. Toluene was found in each sample at concentrations ranging from 5.07 to 65.5 mg/m^3. The lowest occupational exposure criteria are 375 mg/m^3 (NIOSH) for full-shift and 560 mg/m^3 (ACGIH) for short-term exposures. Acetone concentrations ranged from nondetected to 11.5 mg/m^3 on 17 partial-shift personal samples. The lowest occupational exposure criteria are 590 mg/m^3 (OSHA) for full-shift and 2,375 mg/m^3 (ACGIH) for short-term exposures. The remaining three solvents were all less than 1% of the corresponding full-shift exposure criteria which are 180 mg/m^3 for hexane (ACGIH), 435 mg/m^3 for xylene (NIOSH, OSHA and ACGIH), and 340 mg/m^3 for heptane (NIOSH). Two short-term samples for total weight and PNAs had concentrations of 0.89 and 2.13 mg/m^3 for total particulate and from 3.19 to 4.17 ug/m^3 for pyrene and fluoranthene (PNAs). There are no specific criteria for individual PNAs.

Eleven personal samples collected at the ARC Roofing Site had total particulate concentrations of 0.06 to 0.22 mg/m^3. Benzene soluble material was detected on four of the 11 samples. Three PNAs were detected in the air samples at concentrations ranging from 1.4 to 2.1 ug/m^3 for acenaphthalene, nondetected to 1.8 ug/m^3 for fluorene, and nondetected to 1.9 ug/m^3 for naphthalene. There are no specific occupational exposure criteria for individual PNAs. However, a recent NIOSH study has found petroleum asphalt and coal tar pitch fumes to be carcinogenic in laboratory animals.

Fourteen partial-shift xylene personal samples collected at the WR Grace Waterproofing site had air concentrations ranging from 1.68 to 145 mg/m^3. All values are below both short-term (870 mg/m^3-NIOSH) and full-shift (435 mg/m^3-ACGIH) exposure criteria.

The NIOSH investigators believe that weather conditions contributed to the relatively low exposures encountered. Most days were cool (80°F or less) with winds ranging up to 23 mph. These conditions are not unusual for the Chicago area. Also the worksites were all relatively open, without enclosed areas where higher concentrations would be expected.

Based on these results the NIOSH investigators have determined that personal exposures were relatively low for all chemicals evaluated. However, we note that petroleum asphalt and coal tar pitch fumes have been found to be carcinogenic. There is also the potential for higher personal exposures depending on weather conditions and the physical layout of the worksite as well as the possibility of falls or other safety-related injuries.

Recommendations are included in Section VIII to further improve working conditions observed during this survey.

KEYWORDS: SIC 1761 (Roofing and Sheet Metal Work); organic solvents, xylene, toluene, hexane, acetone, heptane, total particulates, benzene soluble fraction, PNAs, pyrene, fluoranthene, acenaphthalene, fluorene, naphthalene, roofing, waterproofing, asphalt

II. INTRODUCTION

On June 27, 1985, NIOSH received a request from an authorized representative of the United Union of Roofers, Waterproofers, and Allied Workers to evaluate employee exposures during the application of single-ply roofing and/or waterproofing systems.

Chicago, Illinois was selected as an appropriate study area due to an established working relationship between the union and the local roofing/waterproofing contractors and the variety of these systems used in the Chicago area.

NIOSH personnel conducted field investigations on August 27-28 and September 10-13, 1985. Results of the investigations were reported by phone to the requestor and representatives of the roofing contractors in January, February, and March 1986.

III. BACKGROUND

The two roofing systems evaluated during this investigation were the American Roofing Corporations (ARC) system and the Carlisle Roofing System. The waterproofing system was made by the WR Grace Company.

Roofing operations have slowly evolved from almost total utilization of hot build-up type systems such as petroleum asphalt and coal tar pitch to more recent innovations of single-ply roofing systems. The newer type systems use a variety of materials and thus application techniques.

The hot build-up systems involve multiple layers of insulation and coal tar or asphalt, whereas single-ply systems have a single membrane layer with a layer of insulation underneath and an optional layer of ballast (i.e., rocks) on top depending on the specifications of the building engineer. There are a variety of techniques used to combine the sheets of roofing membrane after they are rolled out. Materials used in single-ply roofing membranes include rubber, polyvinyl chloride (PVC) and modified bitumen. The Carlisle Roofing system uses a rubber membrane which is attached by applying adhesive to the entire undersurface of the membrane. After the adhesive becomes tacky the membrane is turned over. Next the membrane edges are glued or melted together. Three principal chemicals used in preparing and attaching the membrane were Sure-Seal Bonding Adhesive, Sure-Seal Splicing Cement, and Sure-Seal Splice Wash. These materials all contained toluene as the principal component, with either textile spirits and acetone or heptane as other primary components.

The ARC Roofing System uses a modified bitumen membrane. A 3-foot long propane torch is used to melt the under-layer of the membrane. The torch is part of a metal frame equipped with wheels. As the membrane is rolled out, the torch flame operating at about 400°F (205°C),

melts the undersurface, which then adheres to the sub-layer of insulation. The insulation having been previously fastened to the roof structure using either staples or nails. Each strip of membrane was overlapped a few inches on the previous one to obtain a continuous sheet. All seams were then inspected and repaired as needed using a hand held torch.

Single ply roofing systems are usually installed by crews of 5 to 10 employees, one of whom is a lead worker or supervisor. Time needed to apply a roof varies according to the size of the roof and the number of workers. Smaller roofs can often be applied in about one week.

Waterproofing system application techniques have some similarities to the roofing systems. Once again, advances in technology have resulted in much faster application. The WR Grace Waterproofing System, evaluated as part of this study, was being applied to the foundation of a building under construction. A coat of primer (Bituthene Primer p-3000) whose principal component was xylene, was applied to the area of the foundation to be covered with earth. After the primer coat became tacky, sheets of "Bituthene" a self-adhesive membrane, were applied over the primer. A layer of insulation was placed over the membrane and held in place using small strips of the membrane, until the back-fill (earth) was in place. The crew of 2 to 3 employees completed the waterproofing operation in approximately 5 days.

IV. METHODS

The environmental evaluation included collecting personal air samples for specific chemicals and area air samples to screen for other potential contaminants. For some systems, bulk samples of solvents and adhesives were also collected. The specific samples collected were determined based on the information provided by the requestor and the system manufacturers, in conjunction with information obtained from a literature search conducted prior to the field investigation.

For the Arc Roofing System, air samples were collected for total particulates, benzene solubles, and polynuclear aromatic hydrocarbons. Additionally, screening samples for organics were used to determine if certain hydrocarbons such as toluene, xylene, benzene might be present as decomposition products. Direct-reading air samples for phosgene were collected in the smoke generated by the torching operation.

For the Carlisle Roofing System, air samples for different combinations of solvent vapors were collected. The specific materials analyzed for in the air samples included toluene, xylene, hexane, acetone, and heptane, as these were the major components of the solvents being used. Two separate sampling and analytical techniques were used to determine if any airborne methylene bisphenyl isocyanate (MDI) was present during the use of a roofing chemical (Pourable Sealer) that contained a small percentage of MDI.

For the WR Grace Waterproofing System, air samples were collected for xylene as it was reported to be the principal component of the adhesive materials used. Screening area samples were also collected for organic solvents to determine if any other significant components were present.

For all non-direct reading samples, the collection media of choice was attached via flexible tubing to a battery operated pump calibrated at a known flow rate. All samples, including a representative number of field blanks, were forwarded to NIOSH analytical laboratories for analysis. Table 1 contains additional information on the sampling and analytical techniques used. More detailed discussions on each method are available in the NIOSH manual of Analytical Methods[1].

V. EVALUATION CRITERIA

A. Environmental Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH recommended exposure limits (RELs), by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.[2-8]

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

B. Specific Compounds

Polynuclear Aromatic Hydrocarbons

Polynuclear aromatic hydrocarbons (PNAs) are the constituents of concern in petroleum asphalt and coal tar pitch products. These large molecules (figure 1) contain numerous 6 carbon rings and have been shown to be carcinogenic as a group with certain individual PNAs exhibiting increased carcinogenic capability. There are potentially thousands of PNAs in pitch. Those that are most potent carcinogenically can be separated out of particulate samples using solvents like benzene and cyclohexane. By limiting exposure to the soluble materials the cancer risk is believed to be reduced.[9-11]

Older hot roofing systems used either coal tar pitch or petroleum asphalt materials. Generally coal tar pitch is believed to be more toxic than petroleum pitch due to higher quantities of soluble PNAs. Petroleum asphalt is the residue from the fractional distillation of petroleum products.

NIOSH in a recently completed laboratory study found carcinogenic activity for both petroleum asphalt and coal tar pitch fumes. Additionally, and perhaps more noteworthy NIOSH found increased carcinogenic activity when the pitch roofing materials were heated to 316°C as opposed to heating the materials to 232°C.[12]

Excess risk of lung cancer, oral cancer, and skin neoplasms (benign and malignant) have been found in working populations handling coal-tar products which NIOSH has defined to include coal-tar, coal-tar pitch, and creosote.[7,9]

The acute toxic effects of exposure to coal-tar pitch include skin and mucous membrane irritation mediated directly and more noticeably through photosensitivity reactions of the phototoxic type involving an interaction between the photosensitizing agent (PNAs) and ultraviolet (UV) radiation, a component of sunlight. The mechanism involves the absorption of this radiant energy by the skin and by the PNAs on the skin which can then result in cell damage.[11] As expected, these reactions affect outdoor workers who handle these materials and receive exposure to sunlight. Thus, these reactions are more frequent and severe in the summer and during mid-day.

A TWA exposure of 0.2 ug/m^3 was recommended by the coke oven advisory committee for benzo(a)pyrene under the OSHA 29 CFR 1910.1029 coke oven emissions standards, but was not adopted; and a special NIOSH hazard review of chrysene recommended that it be controlled as an occupational carcinogen. Also, ACGIH includes chrysene and benzo(a)pyrene in its list of industrial substances suspected of carcinogenic potential for man.

For asphalt fumes both NIOSH and OSHA currently have exposure criteria of 5 milligrams asphalt fume per cubic meter of air (mg/m^3).[8,10] ACGIH currently has no exposure criteria.[6,7] Current occupational exposure criteria for coal tar products are 0.1 mg/m^3 for NIOSH and 0.2 mg/m^3 for OSHA and ACGIH.[6,9]

Xylene

Commercial xylene is a mixture of ortho, meta, and para isomers. The mixture is a colorless liquid with an aromatic odor. The vapor may cause irritation of the eyes, nose, and throat. High concentrations may cause dizziness, severe breathing difficulties, loss of appetite, nausea, vomiting, abdominal pain, and reversible damage to the kidney, liver, and eyes. Repeated contact with the liquid may cause a skin rash.[4,5] The current occupational exposure criteria are 435 mg/m^3 as a time-weighted average (NIOSH, OSHA, and ACGIH). NIOSH also has a 10-minute ceiling REL of 870 mg/m^3.[2-8]

Toluene

Toluene is a colorless liquid with an aromatic odor, similar to benzene. Health effects associated with exposure to toluene vapor are similar to the health effects reported for exposure to xylene including irritation of the eyes, skin, and respiratory tract, fatigue, weakness, confusion, headache, dizziness, and drowsiness. High concentrations may cause unconsciousness, and death. Repeated or prolonged exposure to the liquid may cause drying and cracking of the skin.[4,5] Current occupational exposure criteria as a TWA are 750 mg/m^3 for OSHA and 375 mg/m^3 for NIOSH and ACGIH. Short term (10-minute) ceiling criteria are 1875 mg/m^3 for OSHA and 750 mg/m^3 for NIOSH.[2-8]

The empirical formula and chemical structure for all the aforementioned chemicals are presented in figure 1.

VI. RESULTS

For the WR Grace System, 14 partial shift (15 minutes to 3.5 hrs.) personal xylene samples had air concentrations ranging from 1.68 to 145 mg/m^3. All samples were less than 35% of the full-shift occupational exposure criteria of 435 mg/m^3 (NIOSH and OSHA). All samples were also well below the NIOSH short-term exposure criterion of 870 mg/m^3 for a 10-minute period (Table 2).[2-8] Three area air samples for screening organic materials contained trace amounts of toluene. The toluene present represented about 1% of the amount of xylenes on each sample.

For the Carlisle system, 22 personal partial-shift (15 minutes to 3 hrs.) samples had air concentrations ranging from 5.07 to 65.5 mg/m^3 for xylene, and from nondetected to 2.38 mg/m^3 for toluene. Seventeen personal air samples had air concentrations from nondetected to 19.6 mg/m^3 for hexane and from nondetected to 11.5 mg/m^3 for acetone. Heptane was detected on one of four personal samples at a concentration of 2.1 mg/m^3. All these values were below the corresponding full-shift exposure criteria which are: 375 mg/m^3 for toluene, 435 mg/m^3 for xylene, 1800 mg/m^3 for hexane, 180 mg/m^3 for acetone, and 1600 mg/m^3 for heptane (Table 3).[2-8] The results of three area air samples collected for identification of volatile organic components are presented in Table 6. Toluene was a primary component of each sample and n-hexane of two samples. Among the minor components identified were two carcinogens, benzene and methylene chloride. Their presence is interesting, but both were detected on only one of the three samples, at trace quantities on high volume area samples.

Two short-term samples for PNAs were collected during tear off of small areas of the old roof at the Carlisle Roofing site. One sample contained 4.17 ug/m^3 of fluoranthene, while pyrene was measured on both samples at 3.65 and 3.19 ug/m^3 (Table 4). MDl was not detected by either sampling and analytical technique. A total of 4 personal and 10 areas samples were collected while an employee used the Pourable Sealer.

Three PNAs (acenaphthalene, fluorene, naphthalene) were detected in air samples collected at the ARC Roofing site. Air concentrations of 11 personal samples taken ranged from 1.4 to 2.1 ug/m^3 for acenaphthalene, from nondetected to 1.8 ug/m^3 for fluorene, and from nondetected to 1.9 ug/m^3 for naphthalene (Table 6). Direct-reading samples for phosgene taken in the smoke from the torching operation were all non-detected. Most samples were taken within 12 inches of the melting membrane. Some of the participants suggested that plastic bands located on each roll of bitumen could generate phosgene when they were burned. About 20 bands were placed in a metal bucket and torched. Once again no phosgene was detected. Ethyl acetate and toluene were identified in trace amounts in area samples collected during application of the ARC system.

Weather conditions during the three site visits were generally cool and windy (Table 7). The highest dry bulb or ambient temperature was 80°F measured at the Carlisle site. Prevailing winds ranged from 0.5 to 7 mph on the calmest day, and from 5 to 23 mph on the windiest day.

Each of the three work sites investigated had some potential safety hazards. Hazards at both roofing sites include falls from the roofs and slipping on slick roof surfaces. Other potential hazards include possible burns from the torches used for installation of the ARC system. Employee smoking while using flammable chemicals at the Carlisle site. At the water proofing site falling objects from overhead construction activities were a possibility although we did not observe anyone working directly above the waterproofing crew.

VII. DISCUSSION AND CONCLUSION

Based on these results the NIOSH investigators have determined that the air concentrations measured were below existing occupational criteria. We also note that coal tar pitch and asphalt fumes have carcinogenic potential. Ambient temperatures of 80°F or less, relatively windy conditions, and open worksites probably contributed to the low exposures measured. Higher personal exposures are likely when ambient conditions include low wind, hotter temperatures, and more enclosed worksites. As higher temperatures are encountered heat stress is also a possibility.

NIOSH has conducted approximately 25 previous HHE's during which personal exposures to various roofing materials were investigated.[14-35] Nine of these HHE's were conducted in facilities

which produced roofing materials.[14-22] The remaining fifteen HHE's were conducted during application of various roofing systems.[24-35] Table 8 presents a summary of the personal air concentrations measured in these studies.

A range of personal exposure concentrations have been measured. For example, during two studies (HE 81-468-1036, HE 81-432-1105) personal toluene exposures were below 17 ppm (< 64 mg/m^3) on 18 samples. In a third study, however, concentrations on 13 personal samples ranged up to 96 ppm (360 mg/m^3). The highest concentration in our study was 65.5 mg/m^3 (17.5 ppm). In most of the previous HHE's, personal exposure concentrations were below the corresponding exposure criterion. However, exposures to individual PNAs were much higher on several previous HHEs. Highest exposures have been encountered during application and tear off the older type build-up roofs.

Environmental results obtained from previous and current roofing surveys suggest that for the newer type systems, potential safety hazards including falls from roofs, slips on slick roofing surfaces, and injuries from falling objects are probably more likely than over-exposures to roofing chemicals. There are many technical publications which provide information on the prevalent safety hazards and measures to prevent their occurrence. Several of these are included as references.[36-43]

VIII. RECOMMENDATIONS

1. Roofing and waterproofing contractors should make a concerted effort to find out the principal components of the roofing supplies they use.

2. In conjunction with recommendation No. 1, employees should be provided training on the potential hazards of the materials they work with.

3. Due to the increased risk of cancer associated with asphalt and coal tar pitch fumes, exposures should be reduced to the lowest feasible limit. As much as possible employees should stay upwind of the smoke and vapors emitting from the roofing activities.

4. Precautions should be enforced when working conditions anticipated to cause increased personal exposures are encountered. These conditions include hotter ambient temperatures (i.e., above 90°F), little or no prevailing wind, and partially enclosed work areas.

5. Roofing and waterproofing contractors should evaluate potential safety hazards and corresponding preventative measures prior to employees actually beginning the job. The specific hazards will vary depending on the type of system and physical layout of the

worksite. There are a number of information sources including references number 36 through 43 that provide guidelines for controlling specific hazards. One example is the necessity to prohibit smoking when flammable chemicals are used.

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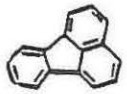
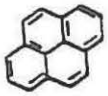
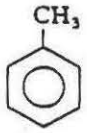
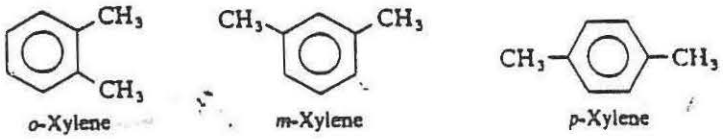
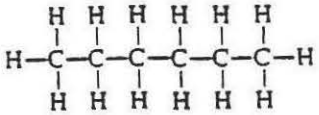
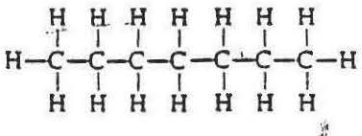
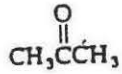
5. United Union of Roofers, Waterproofers and Allied Workers, Local no. 11, Chicago, Illinois
6. NIOSH, Region V
7. OSHA, Region V

For the purpose of informing affected employees, copies of this report shall be posted by the roofing and waterproofing contractors in a prominent place accessible to the employees for a period of 30 calendar days.

Figure 1

Empirical Formulas and Structures for Chemicals
Detected on Personal Samples

Chicago Roofing/Waterproofing Sites
HETA 85-416

Chemical Name	Empirical Formula	Chemical Structure
Acenaphthene	$C_{12}H_{10}$	
Fluorene	$C_{13}H_{10}$	
Naphthalene	$C_{10}H_8$	
Fluoranthene	$C_{16}H_{10}$	
Pyrene	$C_{16}H_{10}$	
Toluene	C_7H_8	
Xylene *	C_8H_{10}	 o-Xylene m-Xylene p-Xylene
Hexane	C_6H_{14}	
Heptane	C_7H_{16}	
Acetone	C_3H_6O	

*Commercial xylene is a mixture of ortho(o), meta(m), and para(a) isomers.

Table 1

Sampling and Analytical Techniques

Roofing and Waterproofing Sites
Chicago, Illinois
HETA 85-416

Contaminant	Sampling Media	Flow Rate (LPM)	Method Number	Analytical Technique
Total Weight and Benzene Solubles	Preweighed Zeflour Filter	2	NIOSH Method No. 5515 (modified)	Total weight determined gravimetrically on an electrobalance. Benzene soluble fractions were analyzed by extracting the sample from the filter using benzene. The extract was filtered through a 0.45 um nylon filter. And 1 ml aliquot was transferred to a tared teflon cup and evaporated to dryness in a vacuum oven. The cups were weighed again to obtain the weight of the aliquot which equals 1/5 of the sample weight.
Organic Vapors: Set A =xylenes (all isomers) Set B = heptane, toluene, xylenes Set C = toluene, acetone, xylenes, hexane	Charcoal Tube	0.2	Modifications of NIOSH Method Nos. 1300, 1500, and 1501	A and B sections of the charcoal tubes were separated and analyzed using gas chromatography. All samples were desorbed for 30 minutes in 1 ml of carbon disulfide containing 1 ul of benzene as an internal standard. All samples were analyzed on a Hewlett Packard Model 5711A gas chromatograph equipped with a flame ionization detector. Oven conditions varied from 35 to 100°C.

(Continued)

Table 1 (Cont.)

Contaminant	Sampling Media	Flow Rate (LPM)	Method Number	Analytical Technique
High Volume Organic Vapors-Screening Samples	Charcoal Tube	1	NM	The A section of each charcoal tube was desorbed in 1 ml of carbon disulfide and analyzed using a gas chromatograph equipped with a flame ionization detector. Any resulting peaks were identified using a gas chromatograph/mass spectrometer.
PNAs	Washed XAD-2 Tube (ORBO-43)	2	NIOSH Method No. 5515 (modified)	Each sample was desorbed and sonicated in 5 ml of benzene. An aliquot was analyzed via gas chromatography.
Methylene Bisphenyl Isocyanate(MDI)	Glass Fiber Filter Impregnated with pyridyl piperazine	1	OSHA Method No. 47 (modified)	High performance liquid chromatograph equipped with a 450 variable wavelength UV detector set at 254 mm. Modifications to OSHA Method No. 47 were utilization of a different column (C_{18}) and no fluorescence detector was used.
Methylene Bisphenyl Isocyanate(MDI)	Glass Fiber Filter Coated with 1-(2-Methoxyphenyl) Piperazine	0.5	Experimental Method No Number Assigned	Samples were extracted with methanol and the excess reagent acetylated with acetic anhydride. Sample extracts were filtered before analysis by isocratic reverse-phase high-performance liquid chromatography This is an experimental method with unknown sample stability and efficiency.
Phosgene	Drager Detector Tube-Phosgene 0.05/a	100cc/ stroke	NM	Direct Reading

NM = No assigned method number.

Table 2

Air Concentration of Xylene During Application of a WR Grace Waterproofing System

Chicago Roofing Sites
Chicago, Illinois
HETA 85-416
September 10-11, 1985

Sample Number	Job	Date	Sample Time	Volume (liters)	Air Concentration mg/m^3
2	Applying Primer to Wall using Roller	9/10	9:08-9:23	2.9	145
5	"	9/10	12:44-12:59	3	96.7
22	"	9/11	8:05-8:20	3	133
23	"	9/11	11:08-11:23	3.2	34.3
26	"	9/11	11:23-11:38	3	96.7
3	Applying Primer with Roller and Attaching Membrane, Carrying Supplies, etc.	9/10	8:17-11:40	11.1	39.6
6	"	9/10	12:44-14:56	7.2	15.7
20	"	9/11	7:57-11:10	9.8	17.3
1	Applying Membrane and/or Insulation	9/10	10:29-10:39	3.1	3.2
4	"	9/10	8:25-11:40	9.8	16.3
7	"	9/10	12:54-14:56	6.1	8.2
21	"	9/11	8:39-11:47	9.4	10.1
28	"	9/11	13:12-14:13	11.7	2.56
25	"	9/11	13:13-14:13	11.9	1.68

Occupational Exposure Criteria (mg/m^3)	TWA	Ceiling
OSHA	435	--
NIOSH	435	870
ACGIH	435	655

Table 3

Air Concentrations of Organic Solvents Measured During Application of a Carlisle Roofing System
Personal Samples

Chicago Roofing Sites
Chicago, Illinois
HETA 85-416
August 27-28, 1985

Sample Number	Job	Date	Sample Time	Volume	Air Concentrations (mg/m^3)				
					Heptane	Toluene	Xylene	Hexane	Acetone*
0	Applying Splice Wash	8/27	11:19-13:26	23.7	2.1	5.07	1.69	-	-
021	"	8/27	11:45-12:00	2.7	ND	7.41	ND	-	-
025	"	8/27	12:49-13:04	3.0	ND	6.67	ND	-	-
057	"	8/28	14:01-14:16	2.9	ND	41.3	ND	-	-
002	Applying Bonding Adhesive-with Machine	8/27	8:31-11:22	34.3	-	35.0	1.17	10.8	7.0
004	"	8/27	9:57-11:29	16.8	-	65.5	2.38	19.6	8.93
042	"	8/28	12:33-14:29	21.4	-	30.4	0.93	7	8.88
001	Applying Bonding Adhesive-with Long Handled Roller	8/27	8:21-11:25	34.3	-	40.8	1.46	14.9	11.1
003	"	8/27	8:43-11:47	34.8	-	43.1	1.44	28.7	11.5
005	"	8/27	10:02-11:47	19.1	-	57.6	2.09	16.2	10.5
058	"	8/28	14:03-14:18	2.9	-	34.5	ND	ND	(6.9)
041	"	8/28	12:30-14:35	24.9	-	24.1	1.2	7.23	6.02
043	"	8/28	12:36-14:35	21.6	-	27.8	1.39	9.72	7.87
044	"	8/28	13:11-13:26	3					
022	Applying Splice Cement	8/27	12:30-12:45	2.7	-	7.4	ND	ND	ND
023	"	8/27	12:30-12:45	2.6	-	7.69	ND	ND	ND

(Continued)

Table 3 (Cont.)

Sample Number	Job	Date	Sample Time	Volume	Air Concentrations (mg/m^3) Heptane	Toluene	Xylene	Hexane	Acetone
U28	"	8/27	13:16-13:31	2.9	-	6.9	ND	ND	ND
U27	"	8/27	13:16-13:31	3.2	-	6.25	ND	ND	ND
U26	Applying Splice Cement	8/27	12:50-13:05	2.9	-	13.7	ND	6.9	(3.44)
U59	"	8/28	14:14-14:29	2.9	-	17.2	ND	6.7	(3.45)
U40	Applying Adhesive, Splice Wash and Splice Cement	8/28	10:54-13:53	33.2	-	8.73	0.6	5.12	ND
U45	Applying Membrane and Bonding Adhesive	8/28	13:26-13:41	2.4	-	20.8	ND	4.17	ND

* = When values are in () the amount in the air sample was above the laboratory limit of detection but below the limit of quantitation.
- = Not evaluated on this sample.
ND = Not detected.

Occupational Exposure Criteria (mg/m^3):

		Heptane	Toluene	Xylene	Hexane	Acetone
As a TWA:	NIOSH	340	375	435	350	2400
	OSHA	2000	750	435	1800	590
	ACGIH	1600	375	435	180	1780
As a ceiling Value:	NIOSH	1760	750	870	1836	none
	OSHA	none	1800	none	none	none
	ACGIH	2000	560	655	-	2375

Table 4

Air Concentrations for PNAs Measured at a Carlisle Roofing Site
Personal Samples

Chicago Roofing Sites
Chicago, Illinois
HETA 85-416
August 28, 1985

Sample Number	Job	Sample Time	Volume	Air Concentration		
				Total Particulate	PNAs Detected	Concentration (ug/m^3)
729	Roofer-Tear off Small Sections of Old Roof	6:50-8:28	192	0.89	fluoranthene pyrene	4.17 3.65
737	"	6:54-8:28	188	2.13	pyrene	3.19

Benzene solubles were below the limit of detection (0.05 mg/filter) on each sample. No specific occupational criteria for these PNAs.

Table 5

Qualitative Analysis of High Volume Area Airborne Screening Samples for Organic Vapors During Application of a Carlisle Roofing System

Chicago Roofing Sites
Chicago, Illinois
HETA 85-416

Sample Number	Activity During Collection	Sample Time	Volume (liters)	Identified Materials	
				Major Components	Minor Components
007	Application of Adhesive	8:58-11:05	127	toluene n-hexane 3-methyl pentane 2-methyl pentane	acetone 2,2-dimethylbutane 2,2,3-trimethylbutane methylcyclopentane 2-methylhexane benzene* n-heptane xylene
20	Splice Wash and Application of Adhesive	11:50-13:38	108	toluene	methyl pentanes xylenes acetone methylene chloride* 2-methyl hexane n-heptane methyl cyclohexane ethyl benzene
46	Application of Adhesive	12:43-14:25	102	toluene methyl pentanes n-hexane	methyl butanes acetone xylene methyl cyclopentane methyl hexane

* This chemical is a carcinogen. Present at a trace quantity, slightly above limit of detection.

Air Concentration of PNA Measured During Application of an ARC Roofing System
Personal Samples

Chicago Roofing Sites
Chicago, Illinois
HETA 85-416
September 12-13, 1985

Sample Number	Job	Date	Sample Time	Volume (liters)	Air Concentrations: Filter (mg/m^3) Total Particulate	Filter (mg/m^3) Benzene Solubles	Tube (ug/m^3) Acenaphthene	Tube (ug/m^3) Fluorene	Tube (ug/m^3) Naphthalene	Tube (ug/m^3) Total PNAs
979, T-1	Roofer	9/12	7:32-11:52 12:35-15:20	850	0.14	LD	1.7	1.5	1.5	4.7
978, T-2	Roofer	9/12	7:44-11:52 12:50-15:18	792	0.14	LD	1.8	1.6	1.8	5.2
972, T-3	Roofer	9/12	7:37-11:52 12:52-15:20	766	0.07	*	1.4	1.3	1.2	3.9
970, T-5	Roofer	9/12	8:16-9:11 10:13-11:52 12:51-15:04	538	0.22	LD	2	1.7	1.9	5.6
962, T-6	Roofer	9/12	9:27-11:52 12:42-15:16	598	0.15	LD	1.7	1.5	1.7	4.9
961, T-25	Roofer	9/13	11:20-12:00 12:48-14:52	328	0.15	LD	2.1	ND	ND	2.1
965, T-20	Roofer	9/13	7:28-12:00 12:49-15:15	836	0.12	*	1.7	1.6	1.6	4.9
955, T-21	Roofer	9/13	7:29-12:00 12:49-14:55	754	0.21	*	1.6	1.5	1.5	4.6
975, T-22	Roofer	9/13	8:20-12:00 12:50-14:52	684	0.12	LD	1.8	1.6	1.5	4.9
971, T-23	Roofer	9/13	9:10-12:00 12:46-15:06	620	0.06	LD	1.9	1.8	1.8	5.5
976, T-24	Roofer	9/13	9:55-12:00 12:50-15:00	510	0.10	*	2	1.6	1.2	4.8

LD = Below the laboratory limit of detection.
ND = Not detected on this sample.
* = Benzene soluble materials were detected on this sample but due to high blank values, concentrations are not reported.

Note: Each sample train consisted of a filter and tube which were both analyzed for 17 specific PNAs. No individual PNAs were detected on the filter sample suggesting that PNAs were in the vapor state. Fourteen of the PNAs were not found on any sample including: acenaphthalene, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(j)fluoranthene, benzo(k)fluoranthene, benzo(e)pyrene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, benzo(g,h,i)perylene.

Table 8

Summary of Environmental Samples Collected During
Previous HHEs of Roofing/Water Proofing Operations

Chicago Roofing Sites
Chicago, Illinois
HETAB 85-416

Reference No.	HE No.	Date of Study	State Conducted In	Principal* Materials Evaluated	Type Sample	No. of Samples	Air Concentration* Range in mg/m^3 (unless noted otherwise)
23	75-102-0304	9/75	Ks	PPOM	Personal	38	<0.2 to 0.49
24	75-194-0324	3/76	Mo	PPOM	Personal	23	<0.01 to 1.88
				PAH	Personal	23	0.06 to 0.25
25	81-403-1024	8/81	Fl	HCL	Personal	15	ND to 1.4 ppm
				HCL-DRT	Area	-	ND to 4 ppm
				CO-DRT	Area	-	Trace
				THF	Personal	10	2 ppm
				MEK	Personal	10	1 ppm
26	81-468-1036	9/81	Md	MC	Personal	10	ND to 31.1
				2-B	Personal	10	ND to 17.6
				TOL	Personal	10	2.8 to 16.6
				XYL	Personal	10	ND to 1.3
27	81-432-1105	10/81	NY	TD	Personal	5	1.8 to 6.2
				RD	Personal	2	0.67 to 1.7
				CS	Personal	11	ND to 0.51
				PNA-FLE	Personal	11	ND to 26 ug/m^3
				PNA-PYR	Personal	11	ND TO 18 ug/m^3
				PNA-BAA	Personal	11	ND to 14 ug/m^3
				CHR	Personal	11	ND to 9 ug/m^3
				PNA-BAP	Personal	11	ND to 11 ug/m^3
				ACE	Personal	8	ND to 13.5 ppm
				TOL	Personal	8	3.4 to 13 ppm
				HEX	Personal	8	1.3 to 13 ppm
				XYL	Personal	8	ND to 0.2 ppm

(continued)

Table 7

Weather Conditions During Environmental Survey
at Chicago Roofing/Water-Proofing Sites

Chicago Roofing Sites
Chicago, Illinois
HETA 85-416

Roofing/Water Proofing System	Date	Ambient Temperature (°F)	Wind Speed	
			FPM	MPH
ARC	9-12	61-66	500-2000	5-23
ARC	9-13	55-67	200-1500	2-17
Carlisle	8-27	63-80	>10-700	>1-8
Carlisle	8-28	66-80	>10-800	>1-9
W.R. Grace	9-10	65-72	50-600	>1-7
W.R. Grace	9-11	61-66	300-1200	3-14

FPM = Feet per minute
MPH = Miles per hour - 1 mph = .88 FPM.
°F = Degrees Fahrenheit

Table 8 (Cont.)

Reference No.	HE No.	Date of Study	State Conducted In	Principal* Materials Evaluated	Type Sample	No. of Samples	Air Concentration* Range in mg/m^3 (unless noted otherwise)
35	83-380-1671	8-9/83	Oh	TP	Personal	6	0.76 to 2.8
				BS	Personal	6	ND to 0.32
				PNA-T	Personal	6	ND
				HEX	Personal	13	3.8 to 72
				TOL	Personal	13	7.7 to 96
				XYL	Personal	13	0.19 to 5.3
				EB	Personal	13	ND to 1.3

State Abbreviations: Ks=Kansas, Mo=Missouri, Fl=Florida, Md=Maryland, NY=New York, Oh=Ohio, WV=West Virginia, Wi=Wisconsin, Pa=Pennsylvania

Chemical Abbreviations:

TP = total particulate
TW = total weight
RD = respirable dust
BS = benzene soluble fraction
CS = cyclohexane soluble fraction
AS = acetonitrile soluble fraction
PPOM = particulate polycylic organic matter
PAH = polynuclear aromatic hydrocarbons
PNA = polynuclear aromatics
PNA-T = Total PNAs
FLE = fluoranthene
PYR = pyrene
BAA = benzo(a)anthracene
CHR = chrysene
BAP = benzo(a)pyrene
BEP = benzo(e)pyrene
PHE = phenanthrene
BGP = benzo(ghi)perylene
AAH-CW = combined weight of aromatic and aliphatic hydrocarbons
HCL = hydrogen chloride/hydrochloric acid
MC = methylene chloride
2-B = 2-butanone
TOL= toluene
XYL = xylene
THF = tetrahydrofuran
MEK = methyl ethyl ketone
DRT = direct reading detector tube
TRIG = total reactive isocyanate group
MDI = methylene diisocyanate
TDI = toluene diisocyanate
EG = ethylene glycol
HEX = hexane
EB = ethyl benzene

*Names of the chemicals sampled for and air concentrations listed are as reported by the authors of the referenced reports

Table 8 (Cont.)

Reference No.	HE No.	Date of Study	State Conducted In	Principal* Materials Evaluated	Type Sample	No. of Samples	Air Concentration* Range in mg/m^3 (unless noted otherwise)
28	82-034-1121	5/82	Oh	CS	Personal	9	0.09 to 2.3
29	82-067-1253	12/81	Oh	BS	Personal	11	0.3 to 1.1
				PNA	Personal	11	0.2 to 39.5 ug/m^3
				PNA	Personal	5	0.2 to 6.3 ug/m^3
30	82-253-1301	5/82	WV	TP	Area	4	0.1 to 1.5
				PNA	Area	1	0.002
31	82-292-1358	6/82	Wi	TP	Personal/Area	10	0.5 to 5.6
				RP	Area	7	0.2 to 5.1
				HS	Personal	6	ND to 6 ppm
				SO_2	Personal/Area	9	0.01 to 0.04 ppm
32	84-221-1523	3/84	Pa	TRIG	Personal/Area	12	ND to 192 ug/m^3
				MDI	Personal/Area	12	ND
				TDI	Personal/Area	12	ND
				XYL	Area	4	trace
				TOL	Area	4	trace
				EG	Personal/Area	11	ND
33	84-062-1552	12/83	Oh	TD	Personal	6	2.1 to 13.1
				BS	Personal	6	0.6 to 5.3
				PNA-FLE	Personal	6	13.3 to 187 ug/m^3
				PNA-PYR	Personal	6	10.6 to 141 ug/m^3
				PNA-BAA	Personal	6	6.8 to 82.9 ug/m^3
				PNA-CHR	Personal	6	6.0 to 71.4 ug/m^3
				PNA-BAP	Personal	6	6.0 to 59.9 ug/m^3
				PNA-BEP	Personal	6	4.3 to 64.5 ug/m^3
				PNA-PHE	Personal	6	10.6 to 161 ug/m^3
				PNA-BGP	Personal	6	3.3 to 43.8 ug/m^3
34	83-198-1646	3-4/83	Mo	AS	Personal	19	0.04 to 0.83

(Continued)