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Asphalt Fume Exposures During the Application of Hot Asphalt to Roofs

Current Practices for Reducing Exposures

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

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DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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FOREWORD

The Occupational Safety and Health Act of 1970 (Public Law 91–596) assures, insofar as possible, safe and healthful working conditions for every working man and woman in the Nation. The act charges the National Institute for Occupational Safety and Health (NIOSH) with recommending occupational safety and health standards and describing exposure concentrations that are safe for various periods of employment—including but not limited to the concentrations at which no worker will suffer diminished health, functional capacity, or life expectancy as a result of his or her work experience.

This document represents the collaborative efforts of industry, labor, and government to protect the health of workers exposed to asphalt fumes during the application of hot asphalt to roofs. Current engineering controls and work practices are presented for reducing worker exposures to asphalt fumes during the application of hot asphalt to roofs. Prevention methods such as these are the cornerstone of public and occupational health.

This document is the result of a public meeting convened on July 22 and 23, 1996, in Cincinnati, Ohio. Participants discussed engineering controls and work practices for controlling exposures to asphalt fumes in the roofing industry. Although the health risks from asphalt exposure are not yet fully defined, all partners agreed that prudent action was needed to reduce worker exposures. They decided to produce a joint document that would describe engineering controls and work practices to reduce worker exposure to asphalt fumes during the application of hot asphalt to roofs. The willingness of all partners to work together in this effort should serve as a model for others who are developing occupational safety and health recommendations. This document was truly a joint effort. I would like to thank the National Roofing Contractors Association (NRCA), the Asphalt Roofing Manufacturers' Association (ARMA), the Asphalt Institute (AI), and the United Union of Roofers, Waterproofers, and Allied Workers (UURWAW) for their cooperation and hard work.

John Howard, M.D.
Director, National Institute for
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ABSTRACT

This document represents a collaborative effort of the National Institute for Occupational Safety and Health (NIOSH), the National Roofing Contractors Association (NRCA), the Asphalt Roofing Manufacturers' Association (ARMA), the Asphalt Institute (AI), and the United Union of Roofers, Waterproofers, and Allied Workers (UURWAW) to reduce worker exposures to asphalt fumes during the application of hot asphalt to roofs. The document describes the application of hot asphalt to roofs, identifies steps in the process that may involve worker exposure to asphalt fumes, and identifies current engineering controls and work practices used to reduce exposures. In addition, the document lists relevant research needed for further reducing asphalt fume exposures during the application of hot asphalt to roofs.

CONTENTS

ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AI	Asphalt Institute
APP	atactic polypropylene
ARMA	Asphalt Roofing Manufacturers' Association
B(a)P	benzo(a)pryene
BUR	built-up roofing
°C	degrees Celsius
CFR	*Code of Federal Regulations*
cm	centimeter(s)
EID	Education and Information Division
EVT	equiviscous temperature
°F	degrees Fahrenheit
f	filter
Fed. Reg.	Federal Register
ft	foot (feet)
gal	gallon(s)
GC/MS	gas chromatography/mass spectrometry
GM	geometric mean
GSD	geometric standard deviation
HEPA filter	high-efficiency particulate air filter
HPLC	high performance liquid chromatography
hr	hour(s)
in.	inch(es)
kg	kilogram(s)
lb	pound(s)
LEL	lower flammable or explosive limit
m	meter(s)
mg	milligram(s)
min	minute(s)
ND	not detected
ng	nanogram(s)
NIOSH	National Institute for Occupational Safety and Health
NRCA	National Roofing Contractors Association
OSHA	Occupational Safety and Health Administration
OV	organic vapor
PAH	polycyclic aromatic hydrocarbon
PBZ	personal breathing zone
PEL	permissible exposure limit

PIB	polyisobutylene
PPE	personal protective equipment
REL	recommended exposure limit
s	sorbent tube
SBS	styrene-butadiene-styrene
TLV	threshold limit value
TWA	time-weighted average
UEL	upper flammable or explosive limit
UURWAW	United Union of Roofers, Waterproofers, and Allied Workers
%	percent
mg	microgram(s)

GLOSSARY

Air blowing: The manufacturing process in which air is blown through an asphalt flux to make oxidized roofing asphalts. An exothermic oxidation reaction occurs, yielding an asphalt that is harder, more viscous, less volatile, and less temperature-susceptible than the asphalt flux used as the feedstock to the process.

Asphalt (CAS number 8052–42–4): A dark brown to black, cement-like semisolid or solid that is the product of the nondestructive distillation of crude oil in petroleum refining. Depending on the crude oil used as a feedstock, the distillation residuum may be further processed, typically by air-blowing (sometimes with a catalyst) or solvent precipitation to meet performance specifications for individual applications [AI 1990b]. Asphalt is a mixture of paraffinic and aromatic hydrocarbons and heterocyclic compounds containing sulfur, nitrogen, and oxygen [Sax and Lewis 1987].

Asphalt, cutback: An asphalt liquefied by the addition of diluents (typically petroleum solvents) [AI 1990b; Roberts et al. 1996; Speight 1992].

Asphalt flux: The residuum (heated sufficiently to flow) that results from the atmospheric and vacuum distillation processes used by petroleum refineries and independent asphalt manufacturers. Asphalt flux is used in the manufacture of some asphalt roofing materials such as saturant asphalts and some modified bitumen products. Asphalt flux is also used as a feedstock in the air-blowing process used to make oxidized roofing asphalt.

Asphalt fumes: The cloud of small particles created by condensation from the gaseous state after volatilization of asphalt [NIOSH 1977].

Asphalt, oxidized-blown or air-refined (CAS number 64742–93–4): Asphalt treated by blowing air through it at elevated temperatures to produce physical properties required for the industrial use of the final product. Oxidized asphalts are used in roofing operations, pipe coating, undersealing for Portland cement concrete pavements, hydraulic applications, membrane envelopes, some paving-grade mixes [AI 1990b], and the manufacture of paints [Speight 1992].

Asphalt, roofing: Asphalt that is refined or processed to meet specifications for roofing.

Built-up roofing (BUR): A system of asphalt-impregnated felt plies sealed and surfaced with hot mopping-grade asphalt. BUR is primarily used in low-slope commercial roofing. The felt plies can be organic (e.g., cellulose), fibrous screen or mat, or polyester fabric.

Coating-grade asphalt: An air-blown or oxidized asphalt used to manufacture roofing materials used in a variety of roofing systems such as asphalt shingles, polymer-modified bitumen roofing, reinforcing and underlayment felts, and roll roofing products.

Fire point: The lowest temperature at which a substance can give off vapors fast enough to support continuous combustion. The fire point is often 5°F (2.8°C) above the flash point [NSC 1996].

Flammable or explosive limits:

Lower flammable or explosive limit (LEL): The minimum airborne concentration of a flammable substance needed to propagate a flame after contact with an ignition source (i.e., the concentration below which the mixture is too lean to propagate a flame) [NSC 1996].

Upper flammable or explosive limit (UEL): The maximum airborne concentration of a flammable substance that will permit propagation of a flame on contact with an ignition source (i.e., the concentration above which the mixture is too rich to propagate a flame) [NSC 1996].

Flash point: The lowest temperature at which a substance can give off enough vapors to form an ignitable mixture with air and produce a flame if an ignition source is also present [NSC 1996].

Flood coat: The surfacing layer of asphalt into which surfacing aggregate is embedded on an aggregate-surfaced built-up roof. A flood coat is generally thicker and heavier than a glaze coat and is applied at approximately 45 to 60 lb/100 ft^2 (2 to 3 kg/m^2).

Modified bitumen system: A roofing system based on membranes manufactured by impregnating or coating one or more fabric plies with a straight run or oxidized asphalt modified using a polymer, usually atactic polypropylene (APP) or styrene-butadiene-styrene (SBS). Modified bitumen systems may be torch-applied or installed by adhesion in hot asphalt or a cold-applied, solvent-based asphalt adhesive (cutback asphalt). Modified bitumen systems are used on low-slope (primarily commercial or industrial) roofs.

Mopping-grade asphalt: An oxidized asphalt used principally in the construction of built-up roofing and some modified bitumen systems; mopping-grade asphalts are produced in four grades (Types I through IV), according to the steepness of the roof.

Saturant asphalt: A nonoxidized or oxidized asphalt, typically an AC-10 or AC-20 grade material, used to manufacture saturated organic felt plies used in the construction of built-up roofing systems, organic felt shingles, and other roofing materials such as roll roofing.

Straight-run asphalt: The residuum of atmospheric and vacuum distillation processes used by petroleum refineries and independent asphalt manufacturers. This asphalt is used in the manufacture of some asphalt roofing materials (e.g., saturant asphalts and some modified bitumen products); it is also used as a feedstock in the air-blowing process used to make oxidized roofing asphalt.

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1 INTRODUCTION

The primary purpose of this document is to increase the awareness of roofing contractors, safety and health professionals, and engineers about current practices used to reduce occupational exposure to asphalt and asphalt fumes during the application of hot asphalt to roofs. This document represents a collaborative effort of the National Roofing Contractors Association (NRCA); the Asphalt Roofing Manufacturers' Association (ARMA); the Asphalt Institute (AI); the United Union of Roofers, Waterproofers, and Allied Workers (UURWAW); and the National Institute for Occupational Safety and Health (NIOSH). During public meetings held in Cincinnati, Ohio (July 22–23, 1996), attendees agreed to develop a series of technical and educational documents that (1) describe the extent of asphalt exposure during the application of hot asphalt to roofs and (2) provide information about measures to reduce asphalt exposures.

This technical document identifies work practices and other control measures that may be effective in reducing worker exposures to asphalt fumes during the application of hot asphalt to roofs. Furthermore, this document is designed to be part of a comprehensive information and education program to be offered by the NRCA and the UURWAW in cooperation with NIOSH.

In a document published in 2000 [NIOSH 2000], NIOSH reviewed the health effects data on asphalt that had become available since the publication of the 1977 criteria document on asphalt [NIOSH 1977]. This review addresses acute and chronic effects of asphalt exposure and is available at the NIOSH Web site (www.cdc.gov/niosh) for readers interested in additional information.

NIOSH, labor, and industry are working together to better characterize and quantify the health risks from asphalt exposure. Representatives of industry, labor, government, and academia met in Cincinnati, Ohio (September 11–12, 2000), and identified research to assess completely the health risks associated with exposure to asphalt. Through these and other efforts of this partnership, effective workplace measures can be developed and implemented to reduce worker exposure to asphalt fumes.

2 BACKGROUND

2.1 COMPOSITION AND USES OF ASPHALT

Asphalt is a dark brown to black, cementitious, thermoplastic material manufactured in petroleum refineries by atmospheric or vacuum distillation; it may also be left as residue after evaporating or otherwise processing crude oil or petroleum. Asphalt is solid or highly viscous at ambient temperatures. This material is an extremely complex mixture containing a large number of high-molecular-weight organic compounds [King et al. 1984]. Asphalt is now the dominant roofing material used in the United States. However, coal tar is still used in some roofing work, usually to conform to government building specifications that require its use [Freese and Nichols, Inc. 1994].

Most of the asphalt used in the United States is in paving (87%) and roofing (11%) operations. The remaining uses include waterproofing, dampproofing, insulation, and paints [AI 1990a]. Asphalt roofing products and systems include shingles and roll roofing, ply felt, built-up roofing (BUR), polyisobutylene (PIB) single-ply systems, and modified bitumen systems made from straight-run or oxidized asphalts modified with polymers, including styrene-butadiene-styrene (SBS) and atactic polypropylene (APP).

2.2 THE ROOFING INDUSTRY

Approximately 46,000 contractors are in the U.S. roofing business today [NRCA 2000]. The industry consists overwhelmingly of small businesses that specialize primarily in residential roofing. This sector of the roofing industry is characterized by relatively high rates of turnover, both in the contractor population and in the workforce. However, the commercial/industrial segment of the industry generally includes larger firms with comparatively greater commercial longevity and relatively lower rates of worker turnover. These differences are due primarily to the significantly higher capital startup costs and technical sophistication required for commercial/industrial roofing systems. In this sector, where work frequently involves hot asphalt, it is common to find workers with 20 to 30 years of experience in the industry. Some of these workers have been employed by the same contractor throughout their careers. The low-slope commercial/industrial sector accounts for 69% of the industry (measured in revenue dollars), according to the most recent NRCA market survey data [NRCA 2000]. In the low-slope roofing sector (primarily commercial, industrial, and multiunit residential buildings), asphalt BUR systems, modified bitumen membrane systems, and asphalt shingles account for 46% of sales in new construction and 53% of reroofing jobs [NRCA 2000].

Currently, the industry estimates that about 50,000 on-roof workers are exposed to asphalt fumes during approximately 40% of their working hours [AREC 1999].

2.3 TYPES AND GRADES OF ROOFING ASPHALTS

The four basic grades of roofing asphalt are (1) coating-grade asphalt, an oxidized asphalt used to make shingles and roll roofing; (2) mopping-grade asphalt, an oxidized asphalt that is melted and used in the construction of

BUR and modified bitumen systems; (3) modified bitumen-based asphalt, a lightly oxidized or nonoxidized asphalt used in saturated felt plies for the construction of BUR systems and in organic felt shingles or organic roll roofing; and (4) saturant-grade asphalt, a lightly oxidized or nonoxidized asphalt used in saturated felt plies for the construction of BUR systems and in organic felt shingles or roll roofing.

The principal physical differences between saturant and coating-grade asphalts are viscosity and softening point. Saturant asphalts typically have a softening point of about 120 to 140 °F (50 to 60 °C), making them less viscous than coating asphalts, which have a softening point of approximately 200 to 225 °F (95 to 105 °C). Despite their lower viscosity, saturant asphalts are processed at significantly higher temperatures (about 425 to 475 °F [218 to 246 °C]) than coating asphalts (about 380 to 460 °F [190 to 238 °C]) because of the need to ensure adequate impregnation of the organic felts that use saturant asphalts [ASTM 1997].

The four types of mopping-grade asphalt are described in Table 2–1. The viscosity of mopping grade asphalts differs among the four types that are produced (see Table 2–1). Type I is the softest (least viscous) grade and is used on very low-slope roofs. Type IV is the hardest (most viscous) grade and is used on the highest slope roofs suitable for BUR systems.

Petroleum refineries and independent asphalt manufacturers produce oxidized roofing asphalt by air-blowing the residuum of refinery atmospheric or vacuum distillation processes. This starting material, termed "asphalt flux," may also be a blend of residue from different sources. In the air-blowing or oxidation process, heated asphalt flux is placed into a tank known as a blowing still, and air is blown through it. The reactions that take place are exothermic, so the temperature is controlled within the range of 400 to 550 °F (204 to 288 °C). The temperature and the amount of air are varied by the manufacturer, depending on the nature of the asphalt flux and the intended characteristics of the oxidized roofing asphalt being produced. This process raises the softening point and viscosity and lowers the penetration and ductility of the asphalt [King et al. 1984; IARC 1985; Corbett 1979].

At the temperatures of the air-blowing process, the oxidations and subsequent reactions ultimately yield compounds of increased polarity and higher apparent molecular weight [Boduszynski 1981; Corbett 1975; Goppel and Knotnerus 1955]. Compared with the asphalt flux, the air-blown asphalts contain an increased proportion of asphaltenes, decreased proportions of naphthene-aromatics, and about the same proportion of saturates* [Corbett 1975; Boduszynski 1981; Moschopedis and Speight 1973]. The process effluent contains water, carbon dioxide, other reaction products, and small amounts of relatively volatile components of the asphalt [Corbett 1975; Goppel and Knotnerus 1955]. The oxygen added to asphalt in the air-blowing process appears to reside in hydroxyl, peroxide, and carbonyl functional groups (the latter includes ketones, acids, acid anhydrides, and esters) [Campbell and Wright 1966; Petersen et al. 1975; Goppel and Knotnerus 1955].

2.4 ASPHALT ROOFING PRODUCTS AND SYSTEMS

Today, three commercially popular roofing products or systems are made from roofing asphalt, each with different characteristics and applications:

*To determine gross composition, asphalt is frequently fractionated by treatment with heptane or a similar hydrocarbon solvent to precipitate the asphaltenes. This step is followed by chromatography of the maltenes (soluble portion) into three fractions, which are (in order of increasing polarity) the saturates, naphthene-aromatics, and polar aromatics [Corbett 1975; Boduszynski 1981].

Table 2–1. Types of mopping-grade asphalt

Asphalt type	Susceptibility to flow at roof temperatures (viscosity)	Highest % slope suitable for use	Softening point °F	Softening point °C
I, dead level	Relatively susceptible	2	135–151	57–66
II, flat	Moderately susceptible	4	158–176	70–80
III, steep	Relatively nonsusceptible	25	185–205	85–96
IV, special steep	Relatively nonsusceptible	50	210–225	99–107

Adapted from ARMA [1996].

- **Asphalt shingles and roll roofing** are used in residential and steep-slope commercial roofing.
- **BUR systems** are asphalt-impregnated felt pieces that are sealed, adhered, and surfaced with hot mopping asphalt. The systems are used in low-slope commercial roofing.
- **Modified bitumen roofing systems** are used in low-slope systems with BUR; or they are used by themselves and adhered with hot asphalt, heat, or adhesives to make the waterproof roofing system.

2.4.1 Asphalt Shingles and Roll Roofing

Asphalt shingles introduced in the early 1900s account today for about 75% of new construction and re-roofing in steep-slope residential and some commercial roofing applications [NRCA 1996]. Today, roll roofing is used mainly in BUR systems on low-slope roofs. With low-slope roofing, smooth-surface roll roofing can be used in building the BUR membrane, and mineral-surfaced roll roofing is used as a cap or top sheet [NRCA 1996; AI 1990a].

Asphalt shingles and roll roofing both consist of a reinforcing felt covered with coating asphalt; organic felts are impregnated with a saturant asphalt. In most cases, asphalt shingles and roll roofing contain a surfacing material—usually coarse or fine mineral. Asphalt shingles and roll roofing are installed using mechanical fasteners or cold-applied adhesives; they do not require hot mopping asphalt. In addition, both products are typically installed over an underlayment felt that has been impregnated with coating asphalt during manufacture [NRCA 1996].

2.4.2 BUR Systems

BUR systems were introduced in the late 1800s and remain the most popular roofing system for commercial and industrial buildings. These systems account for about 20% of the new and retrofit markets for low-slope roofs [NRCA 2000]. The BUR membrane is composed of layers (or moppings) of mopping asphalt between felt plies of saturant asphalt or coating asphalt reinforcing fabric such as organic felts (e.g., cellulose), fiberglass scrim or mat, or polyester fabric. BUR membranes are installed in multiple-ply configurations that typically involve three to six interply moppings of mopping asphalt. In addition, a weatherproofing top layer is applied—either in the form of (1) roll roofing made from organic or inorganic materials or (2) a flood coat† of mopping asphalt (usually Type I).

All three grades of roofing asphalt (coating, saturant, and mopping) may be used in the manufacture or construction of BUR systems:

†Flood coat is the surfacing layer of asphalt into which surfacing aggregate is embedded on an aggregate-surfaced BUR. A flood coat is generally thicker and heavier than a glaze coat and is applied at approximately 45 to 60 lb/100 ft^2 (2 to 3 kg/m^2).

saturant asphalts are used to manufacture organic felts and roll roofing; coating asphalts are used for virtually all felt ply and roll goods; and heated mopping asphalts are used for the interply moppings and, in some cases, the flood coats applied in constructing the BUR membrane [NRCA 1996].

2.4.3 Modified Bitumen Roofing Systems

Polymer-modified bitumen roofing systems were introduced in the 1970s and today account for about 18% of the new construction market and about 23% of the re-roofing market for low-slope (i.e., primarily commercial and industrial) roofs [NRCA 2000]. Modified bitumen products are of two types: (1) those made primarily with APP and (2) those made primarily with SBS as the polymer modifier.

APP membranes are primarily torch-applied—that is, they are made to adhere to an underlying base sheet onto the manufacturer's approved substrate by heating the back side of the APP membrane and the substrate with high-intensity, propane-fired torches or specially designed hot-air welders. The heat is applied only as needed to soften the asphalt and make the modified bitumen membrane adhere to the substrate; these products can also be cold-applied with adhesives. SBS membranes may be applied by adhesion in hot asphalt or in a cold-applied, solvent-based asphalt adhesive; or they may be torch-applied [NRCA 1996].

3 SOURCES OF ASPHALT FUME EXPOSURE

The purpose of this chapter is to describe processes involved in the installation of BUR systems and the potential sources of worker exposure to asphalt and asphalt fumes. Only three low-slope roofing membrane systems—BUR, SBS modified bitumen, and PIB single-ply systems—are installed using hot asphalt. Because the equipment and operations that may result in worker exposures to asphalt fumes are the same in all three types of work, the discussion in this section addresses BUR jobs, which are more common. The same engineering controls and work practices can be used to reduce worker exposure to asphalt fumes during the installation of SBS modified bitumen and PIB single-ply systems.

3.1 TYPICAL BUR SYSTEM

The BUR roof membrane is designed to provide an asphalt-based membrane that serves as a water-impermeable covering for the roof assembly and the building as a whole. The membrane prevents water from entering the building and protects the underlying insulation and roof deck from damage caused by moisture. A typical BUR membrane consists of three basic components: (1) waterproofing material (asphalt or coal tar), (2) reinforcement material, and (3) surfacing material [NRCA 1996]. The reinforcement material (which is critical to the longevity, durability, and stability of the membrane) consists of the ply material embedded between layers of asphalt and the waterproofing material. The reinforcement material helps hold the waterproofing asphalt in place and adds tensile strength and other physical properties to the membrane. Surfacing materials (such as aggregate or mineral granules) protect the membrane from the effects of sunlight and weather exposure and may provide other benefits such as fire resistance. Some surfacing products also improve climate control by acting as solar reflectors. Granules are usually factory-applied to a premanufactured sheet or aggregate (such as pea gravel, slag, or marble chips), or they may be field-applied in a final flood coat of asphalt. The cap or final surface layer of asphalt (sometimes coal tar pitch) is usually applied with a spreader followed by another spreader that applies a layer of gravel [NRCA 1996].

3.2 DELIVERY AND HEATING OF ASPHALT

Mopping-grade roofing asphalt used in the construction of BUR systems is often delivered to the worksite as a solid, typically in the form of 100-lb cartons or kegs. When delivered in solid form, the asphalt is then broken into smaller pieces, manually inserted into a roofing kettle, heated, and pumped to the roof for application. Although asphalt may also be delivered in a tanker as a heated liquid, this practice is increasingly unusual because of cost and product supply considerations. Asphalt delivered by tanker may be heated to the proper temperature in the tanker and then pumped to the roof, or it may first be transferred to a kettle for heating before pumping to the roof.

3.2.1 Kettles

Asphalt roofing kettles come in capacities of 25 to 1,500 gal. Figure 3–1 illustrates 80- and 200-gal kettles.

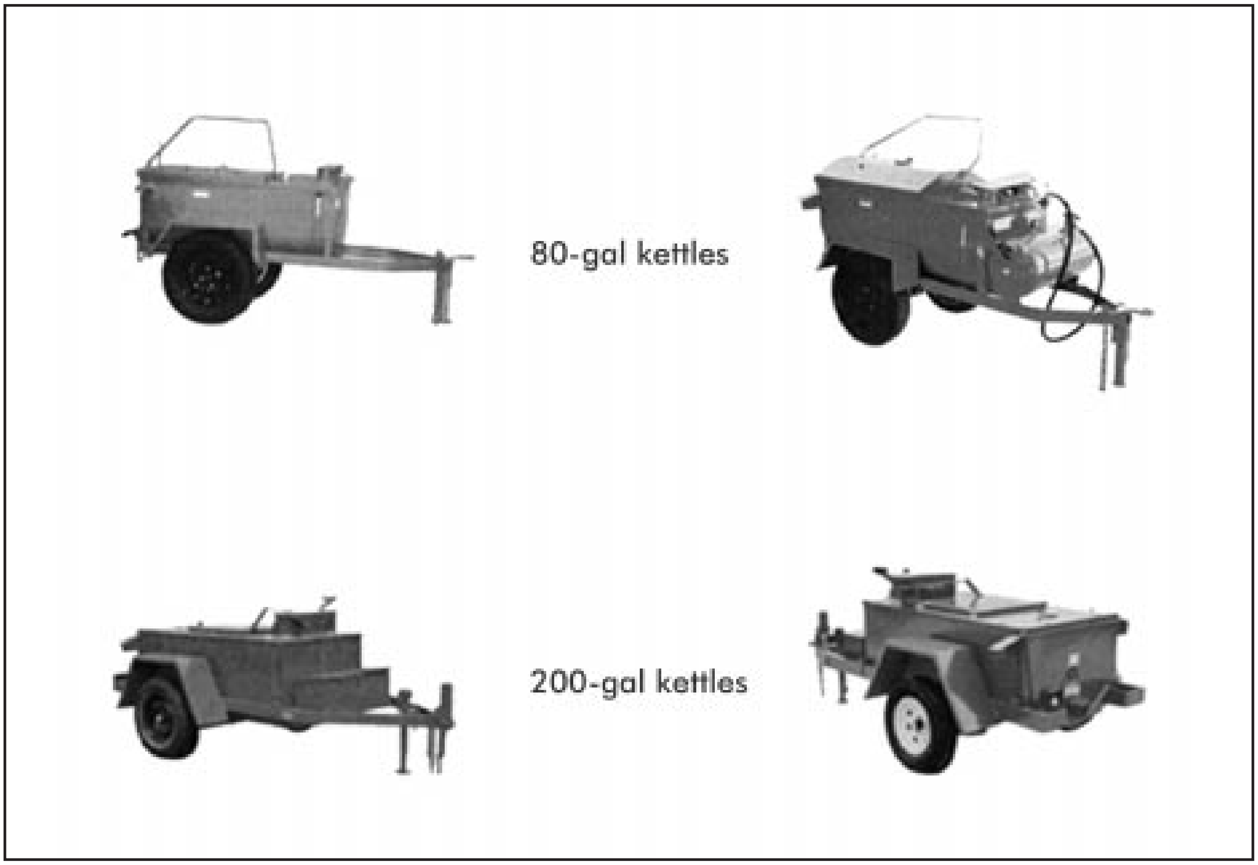

Figure 3–1. Kettles with 80- and 200-gal capacities.

Kettles typically consist of a round-bottomed steel vessel, a heating unit, a motor and pump, and a supply line (often called the hot pipe). The heating unit consists of propane-fired burners and metal heating tubes inside the vessel that distribute heat from the burners to the contained asphalt. The pump circulates the asphalt within the vessel to help maintain even heat distribution, and it is used to deliver the asphalt up the hot pipe to the roof. Kettles may also be equipped with thermometers, thermostats, automatic temperature controls, and other control devices. Figure 3–2 depicts a thermometer on a kettle.

Potential exposures to asphalt fumes related to operation of the kettle include both continuous exposure to fumes that escape from the kettle during operation and intermittent exposures related to the performance of operations such as filling or loading, which require the lid to be

Figure 3–2. Thermometer on a kettle.

opened. Even with a relatively good seal between the body of the kettle and the lid, asphalt fumes can escape from the kettle lid and vents.

The kettle operator may be exposed to asphalt fumes whenever the kettle lid is opened—most frequently for loading. As asphalt is drawn from the kettle, it must be loaded with chunks of asphalt. To load the kettle, the kettle operator must lift the lid of the kettle to insert these chunks (Figure 3–3).

Several other operations require an open kettle lid. For example, the lid may be opened periodically to check the level of liquid asphalt inside the kettle. This step is necessary to ensure that the supply of asphalt is adequate to perform the job task and to maintain the fluid level above the heating tubes to avoid a fire or explosion hazard. The kettle lid is also opened periodically to skim debris from the surface of the asphalt. Removal of surface debris is necessary to avoid clogged pumps and obstructions in the pipe that transports asphalt to the rooftop, to prevent fires, and to ensure a satisfactorily installed roof. In addition, the lid must be opened when checking the temperature with a hand-held thermometer. The use of devices such as dipsticks and automatic thermostats can minimize the number of times the kettle lid needs to be opened.

Figure 3–3. Loading the kettle.

3.2.2 Tankers

Like kettles, tankers contain heating tubes and pumps to circulate and maintain proper asphalt temperatures. During unloading, a pump and supply line are used to pump the material from the tanker to the point of application, kettle, or storage tank. Whenever large quantities of asphalt are pumped or drawn from the tanker, the hatch on top of the tanker must be opened for both operational and safety reasons. Tankers are typically capable of pumping about 60 gal/min, which is the same rate as most kettles manufactured today.

When a tanker is used to refill a kettle, the kettle lid must be open and the kettle operator must be in the area to monitor the fill level and avoid overflow. The kettle is usually top-loaded. Although the kettle lid must be open during filling, it is usually open for a relatively short period, since the high pumping rates of the tankers allow the operation to proceed much faster than manual filling with solid chunks of asphalt.

3.2.3 Asphalt Heating and Application Temperature

The quality of the finished roof depends greatly on the application temperature of the asphalt. The recommended application temperature for mopping-grade roofing asphalts ranges from 330 to 445 °F (166 to 229 °C), depending on the mopping-grade type (Type I, II, III, or IV) [NIOSH 2000]. To achieve the specified asphalt temperature at the point of application, the temperature of the asphalt in the kettle has been reported to be as high as 600 °F (316 °C) [Puzinauskas 1979; Hicks 1995; NIOSH 2000].

To create the proper matrix between the hot asphalt and the felt plies, the liquid asphalt must be applied within a temperature range known as the equiviscous temperature (EVT). The EVT is the temperature at which the viscosity of the asphalt, when applied, will result in a quality roofing system [NRCA 1991; ARMA 1993; NIOSH 2000]. By definition, each asphalt has two EVT values—one for hand mopping and one for mechanical spreading. If the asphalt is applied by hand mopping, the EVT is the temperature at which the viscosity of the asphalt is 125±25 centistokes. If the asphalt is applied using a mechanical spreader, the EVT is the temperature at which the viscosity of the asphalt is 75±25 centistokes. Since the desired viscosity is not a precise value, the EVT is reported as the midpoint temperature ±25 °F (±14 °C) that will result in the desired viscosity range. According to current practice in the industry, the asphalt temperature is measured just before application to the roof surface—that is, the temperature of the asphalt is measured in the mop cart or mechanical spreader, the last point at which temperature can practicably be measured [NRCA 1996]. Because of significant differences in typical application rates of hot asphalt to the roof surface, the EVT is generally about 25 °F (14 °C) higher when a mechanical spreader is used than when mops are used to apply the asphalt [NRCA 1996]. Asphalt at the EVT will be the proper viscosity, depending on application technique; so it may be spread evenly to the optimum thickness and result in the proper matrix between the asphalt and the felt plies. Hot liquid asphalt fuses with the saturation or impregnation asphalt already in the layers of ply felt, thus laminating the plies together to form a strong, waterproof membrane. Again, this result is best achieved when the asphalt is applied at the appropriate EVT [NRCA 1996].

Although EVTs for asphalts of the same classification (i.e., mopping asphalt Types I through IV) tend to be similar across the industry, each EVT is unique to the particular production run of mopping-grade asphalt made by manufacturers. Today, nearly all manufacturers and suppliers of mopping-grade asphalts provide product specifications on the packaging of each keg of solid asphalt distributed to contractors or in the bill of lading accompanying each load of bulk liquid asphalt delivered by tanker truck. The information specifics include the type of asphalt, two EVTs (one for use with the mechanical spreader and the other for use with the mop), the EVT ranges for hand mopping and mechanical spreaders, and other pertinent product characteristics such as the flash point (which is also a value unique to each asphalt product).

Application within the EVT range is also critical to assure proper film thickness of the layers of asphalt. Temperature determines the viscosity of the asphalt. An overheated asphalt will be too thin, whereas an underheated asphalt will be too thick. If the asphalt is overheated for a prolonged period, a phenomenon known as “fallback” can occur. Fallback causes a reduction in the softening point of the asphalt and can affect the quality of the roof system. Such lowered-softening-point asphalts, for example, are prone to “slippage,” which allows the bitumen and reinforcement to slide down-slope [NRCA 1996; Owens Corning 1993]. Fallback is an additional reason that kettle temperatures should be monitored closely and kept only as high as needed to compensate for heat loss during travel from the kettle to the roof.

Asphalt temperatures in kettles and tankers depend on safety and operational considerations. Since several ignition sources exist during kettle operations, safety hazards are created if the temperature is allowed to rise above the flash point or fire point of the asphalt. Flash fires can occur if the temperature of the asphalt reaches or exceeds the flash point; however, continuous combustion can occur if the temperature of the asphalt reaches or exceeds the fire point, which is usually about 5 °F (2.8 °C) above the flash point [NSC 1996]. Some State and local laws limit kettle temperatures for fire safety or environmental protection purposes. Potential sources of ignition during kettle operation include exposed hot metal heating tubes and exhaust stacks, open flames, and hot carbon and coke buildup inside the kettle.

In conventionally configured kettles, fires are a concern when the kettle lid is open or closed. When the lid is open, these fires can lead to very serious burns. In addition, if kettle fires are not contained and immediately extinguished, they can spread to exterior parts of the kettle, engulfing the equipment (including gasoline tanks on some models), solvent containers, and propane fuel tanks with catastrophic results. In addition to fire hazards, explosion hazards exist if the headspace fume concentration is between the lower flammable or explosive limit (LEL) and the upper flammable or explosive limit (UEL). If the kettle temperature is near the flash point, care needs to be taken when opening the kettle lid because the ambient air entering the kettle can lower the fume concentration so that it is between the explosive limits. It is therefore recommended that kettle temperatures always be maintained at least 25 °F (14 °C) below the flash point of the asphalt [NRCA 1996].

Operational factors also influence kettle temperatures. To ensure that the asphalt is the proper temperature at the point of application on the rooftop, the temperature in the kettle must be maintained at a temperature somewhat higher than EVT. How much higher depends on a number of factors that vary from job to job, including the following:

- Environmental factors such as temperature and wind velocity
- Distance the asphalt must be pumped through the hot pipe from the kettle to the roof
- Pumping rate, which may range from 35 to 60 gal/min
- Presence or absence of insulation on the hot pipe and on the hot lugger (used as the primary holding vessel on the roof)
- Distance and time required to transport the asphalt on the roof from the hot lugger to the point of application
- Rate of asphalt usage during the job (the longer the asphalt stays in the hot lugger, the greater the temperature loss)
- Use of closed vessels or lids on rooftop vessels and equipment such as hot luggers, mechanical asphalt spreaders, and felt-laying machines

The range of temperature drop that may occur because of these factors generally averages from about 20 °F (11 °C) to more than 50 °F (28 °C). Many roofing contractors use a 50 °F (28 °C) rule of thumb to determine the appropriate temperature setting for the kettle. Thus an appropriate starting point for kettle temperature may be 50 °F (28 °C) above the EVT midpoint, as long as this temperature is at least 25 °F (14 °C) below the open cup flash point. From this starting point, the kettle temperature can be adjusted up or down to account for actual temperature loss between the kettle and point of application.

On the roof, asphalt temperatures in mop carts and mechanical spreaders can be measured using hand-held thermometers. Measuring the temperature of the asphalt in the kettle may also be accomplished by using hand-held thermometers. In addition, infrared thermometers are available to measure asphalt temperature remotely; point the infrared thermometer gun at the asphalt surface after stirring to get a true reading.

Most kettles manufactured today have built-in thermometers—typically 2.5- to 3.5-in. stem thermometers that are usually screwed into the rear of the kettle vat. However, they are not always placed in the most appropriate location and may be susceptible to damage from heat and physical stress. This is particularly true in the case of older models, which may not have built-in thermometer guards and may require the kettle operator to manually regulate the firing torch of the kettle-heating source according to the asphalt temperature readings. Kettles (particularly models introduced since the late 1970s) may have temperature regulators that automatically control the heating source. Automatic controls include self-contained thermocouple controls, thermostat hi-lo controls, and electric-battery-operated controls.

3.3 INSTALLATION OPERATIONS ON THE ROOF

Installation of a BUR membrane often begins with the application of a base sheet of medium- or heavy-weight felt, although the need for a base sheet depends on the design specifications for the job. The base sheet serves to separate the BUR membrane from the roof substrate, provides support, and cushions the membrane over rough or irregular spots. The base sheet may be attached to some roof decks using mechanical fasteners. Hot asphalt and ply felt are then applied sequentially onto the base sheet. Asphalt at its EVT is mopped or mechanically applied in a thin layer, then the ply felt or ply sheet is rolled into it. It is critical that the asphalt be spread evenly so that it forms a continuous film without gaps or voids beneath the ply felt. Felt plies are laid in an overlapping edge arrangement, and the crew must be sure to maintain adequate side, end, and head lap among the sequential layers of ply felt.

The hot asphalt used in this process is delivered to the roof through a metal supply line (the hot pipe) from the kettle or tanker. The same pump that recirculates the asphalt inside the kettle is typically used to pump the hot asphalt through the supply line to the roof. Standard pumping rates range from 35 to 60 gal/min. Hot pipes are 5- to 20-ft lengths of metal tubing that can be coupled together. Figure 3–4 shows a typical pumping and hot pipe arrangement.

Asphalt delivered through the supply line is usually emptied into a container on the roof called a "lugger" or a "hot lugger," which comes in standard sizes of 30 and 55 gal and is top-filled directly from the supply line. Most luggers have a hatch cover that can be closed once the vessel is filled. Figure 3–5 shows a typical hot lugger and mop bucket.

After delivery into the hot lugger, asphalt may be drawn off in three different ways for use in installing the BUR. In manual application operations, asphalt is drawn off either directly into mop carts or into buckets (see Figure 3–5) that are poured into mop carts for use by workers in the mopping and felt-laying operation. Alternatively, the asphalt may be unloaded directly into mechanical asphalt spreaders or mechanical felt-laying machines, which can be used to lay down the felt and apply the interply layers of asphalt. In all cases, the asphalt is drawn off from the lugger through a spigot or valve and is top-loaded into the receiving vessel. Mechanical felt-laying machines (see

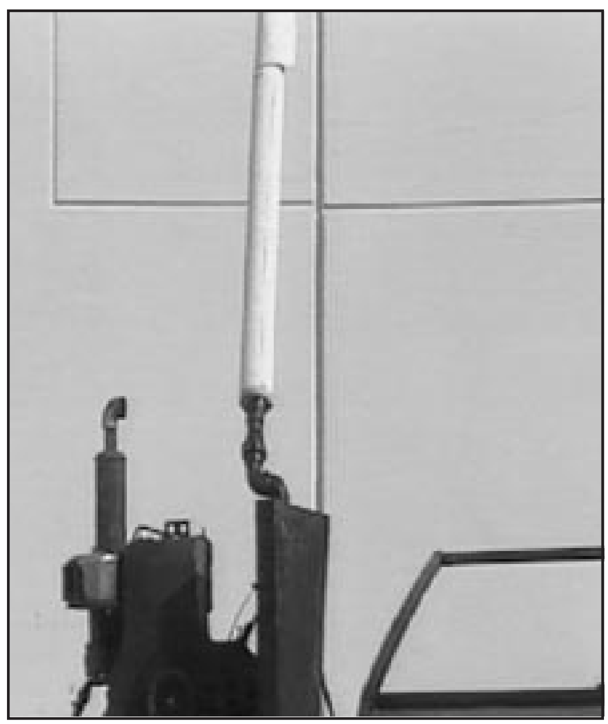

Figure 3–4. Typical pumping and hot pipe arrangement.

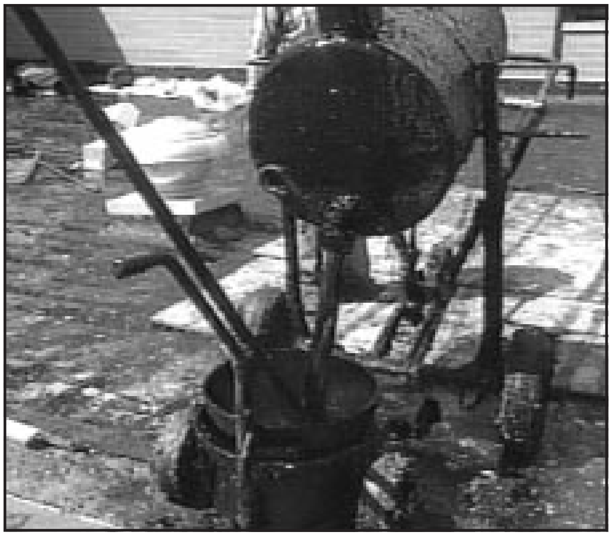

Figure 3–5. Typical hot lugger and mop bucket.

Figure 3–6) typically have lids that can be closed once the vessel is full, but mop carts and simple mechanical spreaders do not.

Manual installations are done with hand-held mops in a procedure that is much like mopping a floor. The carts or buckets that hold the hot asphalt are open at the top because the mop is continually dipped into the container. Mechanical asphalt spreaders, such as felt layers, have closeable lids because there is no need to enter the container to remove the asphalt. The hot asphalt is dispensed onto the substrate through a series of valves on the bottom of the machine.

Figure 3–6. Mechanical felt-laying machine

4 EXPOSURE TO ASPHALT AND ASPHALT FUMES

4.1 OCCUPATIONAL EXPOSURE LIMITS

Currently, no Occupational Safety and Health Administration (OSHA) standard exists for asphalt fumes. In a 1988 proposed rule on air contaminants, OSHA proposed a permissible exposure limit (PEL) of 5 mg/m^3 as an 8-hr time-weighted average (TWA) for asphalt fume exposures in general industry. This proposal was based on a preliminary finding that asphalt fumes should be considered a potential carcinogen [53 Fed. Reg.* 21193]. 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 [54 Fed. Reg. 2679]. In 1992, OSHA published another proposed rule for asphalt fumes that included a PEL of 5 mg/m^3 (total particulates) for general industry, construction, maritime, and agriculture [57 Fed. Reg. 26182]. Although OSHA invited comment on all of the alternatives, its proposed standard for asphalt fumes would establish a PEL of 5 mg/m^3 (total particulates) based on avoidance of adverse respiratory effects. The OSHA docket is closed, and OSHA has not scheduled any further action.

In a 1977 criteria document [NIOSH 1977], NIOSH established a recommended exposure limit (REL) of 5.0 mg/m^3 as a 15-min ceiling limit for asphalt fumes measured as total particulates. The NIOSH REL was intended to protect workers against acute effects of exposure to asphalt fumes, including irritation of the serous membranes of the conjunctivae and the mucous membranes of the respiratory tract. In 1988, NIOSH (in testimony to the Department of Labor) recommended that asphalt fumes be considered a potential occupational carcinogen [NIOSH 1988]. In a later document [NIOSH 2000], NIOSH published a review of the health effects data available since the publication of the 1977 criteria document [NIOSH 1977]. This review is available at the NIOSH Web site (www.cdc.gov/niosh).

The current American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for asphalt fume is 0.5 mg/m^3 (benzene-soluble aerosol of the inhalable fraction) as an 8-hr TWA concentration with an A4 designation, indicating that it is not classifiable as a human carcinogen [ACGIH 2002].

4.2 EXPOSURE DURING ASPHALT ROOFING OPERATIONS

Information is limited about the extent of worker dermal and airborne exposure to asphalt fumes during the application of hot asphalt to roofs. In general, asphalt fume exposures determined from personal-breathing-zone (PBZ) samples collected at different worksites indicate that total particulate and soluble fraction concentrations can be highly variable. Differences in reported PBZ concentrations are most likely a result of the following factors: (1) environmental conditions (wind velocity, temperature) at the worksite, (2) the type of sampling and analytical method used to collect and evaluate exposures, (3) other work tasks (e.g., tear-off of old roof) that may contribute to worker

Federal Register. See Fed. Reg. in references.

exposure, (4) the work practices used in operating the kettle and applying asphalt (e.g., location of the kettle at the worksite, frequency of opening the kettle lid, type of asphalt and asphalt temperature, the manner in which workers apply asphalt to the roof relative to the wind direction), and (5) the length of time in which the PBZ sample was collected during the work shift. Controlled studies by Franzen and Trumbore [2000] found that increasing kettle temperatures from 500 °F (260 °C) to 550 °F (288 °C) caused a dramatic twofold increase in measurements of total suspended particulates and the benzene soluble fraction. However, opacity readings, which measure the visibility of the fumes, were the same at both temperatures.

4.2.1 Airborne Exposures

Pertinent exposure results determined from PBZ samples collected from the 1970s through the 1990s are summarized below and listed in Table A–1 of Appendix A. In the 1970s, NIOSH conducted industrial hygiene studies of roofers applying hot asphalt to roofs. Airborne geometric mean (GM) fume concentrations (benzene solubles) ranged from <0.04 to 2.1 mg/m^3 [Brown and Fajen 1977a,b,c]. In another NIOSH industrial hygiene study, fume concentrations were reported as cyclohexane solubles, and a GM concentration of 0.05 mg/m^3 was found for roofers applying hot asphalt [Hervin and Emmett 1976]. Puzinauskas [1979] reported similar PBZ fume concentrations for roofers applying Type III roofing asphalt. GM asphalt fume concentrations ranged from 0.8 to 2.1 mg/m^3 (benzene solubles) and from 1.2 to 2.9 mg/m^3 (total particulates) for all Type III roofing asphalts evaluated.

Industrial hygiene studies conducted by NIOSH in the 1980s found PBZ fume concentrations comparable to those reported in the 1970s. Reed [1983] and Zey et al. [1988] found PBZ fume concentrations (benzene solubles) ranging from a GM of 0.9–1.2 mg/m^3 and from not detected (ND) concentrations to 1.4 mg/m^3 (no GM determined), respectively, when hot asphalt was being applied to roofs. Similar PBZ sample results were reported by other NIOSH investigators [Tharr 1982; Carson 1986] when either cyclohexane or acetonitrile was used as the extracting solvent for determining asphalt fume concentrations. Tharr [1982] reported GM fume concentrations ranging from 0.17 to 0.28 mg/m^3 (cyclohexane solubles), and Carson [1986] found GM concentrations ranging from 0.16 to 0.27 mg/m^3 (acetonitrile solubles) for workers operating the kettle and applying hot asphalt to roofs. For roofers laying felt, Brandt et al. [1985] reported similar PBZ exposures ranging from 0.2 to 1.1 mg/m^3 (benzene solubles) and 0.5 to 1.7 mg/m^3 (total particulates). The GM concentrations for the kettle operator were higher (4.3 mg/m^3 benzene solubles and 5.1 mg/m^3 total particulates).

In the early 1990s, Schneider and Susi [1993] and Susi and Schneider [1995] reported the results of an industrial hygiene study in which short-duration (11- to 296-min) PBZ samples were collected for the kettle operator and workers applying hot asphalt to roofs. Total particulate concentrations ranged from 10.4 to 28.85 mg/m^3, with a single benzene soluble concentration of 21.8 mg/m^3 for the kettle operator. Total particulate and benzene soluble concentrations for all other workers handling hot asphalt ranged from <0.03 to 3.66 mg/m^3 and 0.08 to 1.89 mg/m^3, respectively.

In a cross-sectional exposure assessment study conducted for AI [AI 1991; Hicks 1995], 38 full-shift PBZ samples (sampling periods ranged from 7 to 9 hr) were analyzed from workers involved in the application of hot asphalt to roofs. GM asphalt fume concentrations ranged from 0.36 to 1.0 mg/m^3 (total particulates) and 0.19 to 0.67 mg/m^3 (benzene solubles). In a recent industrial hygiene study of workers applying asphalt to roofs [Exxon 1997; Gamble et al. 1999], GM asphalt fume concentrations were

0.17 to 0.44 mg/m^3 (total particulates) and 0.06 to 0.16 mg/m^3 (benzene solubles). The highest concentrations of total particulates (2.73 mg/m^3) and benzene solubles (1.23 mg/m^3) were found for a roof laborer. Asphalt fume concentrations reported in the more recent exposure assessment studies of roofers [Exxon 1997; Gamble et al. 1999] are somewhat lower than those reported in the 1970s and 1980s. However, no one has conducted comprehensive studies that have related the use of engineering controls, work practices, and worker education to reduced exposures for workers.

Exposures to polycyclic aromatic hydrocarbons (PAHs) have also been evaluated at roofing sites [AI 1991; Hatjian 1995; Hatjian et al. 1997; Hicks 1995]. Hatjian [1995] and Hatjian et al. [1997] reported the results of PBZ samples collected for asphalt roofers using gas chromatography/mass spectrometry (GC/MS). Napththalene, acenaphthene, and phenanthrene accounted for ≥84% of the measured PAH exposure for roofers. Only one roofer had more than one of three PBZ samples with detectable concentrations of the carcinogenic benzo(a)-pyrene (B[a]P); the highest B(a)P concentration reported was 0.2 $\mu g/m^3$. The kettle temperature at this site was 572 °F (300 °C).

Hicks [1995; AI 1991] also collected and analyzed PBZ samples for specific PAHs (see Table 4–7 in NIOSH [2000]). Several types of PAHs were identified in these samples, including the carcinogenic benzo(b)fluoranthene in three PBZ samples. The temperature of the product at the fume source ranged from 325 to 600 °F (163 to 316 °C). The method used in the Hicks study was high-performance liquid chromatography (HPLC) with an ultraviolet/fluorescence detector. This method lacks the resolution to reliably identify and quantify discrete PAHs in asphalt fumes (see Section 3.5.3 in NIOSH [2000]).

The Hatjian [1995] and Hatjian et al. [1997] studies as well as the Hicks [1995] study indicate that PAHs may be generated in various asphalt operations under some condition of use. Moreover, asphalt fumes generated at high temperatures are probably more likely to generate carcinogenic PAHs than fumes generated at lower temperatures. At some roofing sites, temperatures have been noted to range from 572 °F (300 °C) [Hatjian 1995; Hatjian et al. 1997] to 600 °F (316 °C) [Hicks 1995].

4.2.2 Dermal Exposures

To evaluate the extent to which dermal absorption of PAHs may contribute to the total body burden, Wolff et al. [1989] and Hicks [1995] collected skin wipe samples from workers exposed to asphalt during the application of hot asphalt to roofs. The HPLC/fluorescence technique used by these authors cannot reliably identify and quantify components in asphalt, but their results are presented for completeness.

Wolff et al. [1989] collected 10 skin wipes (forehead) and 9 PBZ samples from 10 roofers who had removed an old coal-tar-pitch roof and replaced it with an asphalt roof. PAHs were detected in PBZ samples of these roofers on separate days using HPLC/fluorescence according to NIOSH Method 5506 [NIOSH 1984]. Evaluation of skin wipe samples indicated that total PAH residues per square centimeter of skin were higher in post-shift samples. A significant correlation (r=0.97) was determined between total PAHs found in PBZ samples and in post-shift skin wipe samples of eight of nine roofers. The workers who performed only coal-tar-pitch tear-off all day had higher total PAHs in post-shift skin wipes and PBZ samples than did workers who performed both tear-off and roof replacement. The source of PAHs could not be ascertained during the period when workers applied hot asphalt only, since samples were collected during the entire roof replacement (which also involved the removal of the old coal-tar-pitch roof).

In addition, PBZ samples and skin wipe samples were collected at the end of the work shift from either the foreheads or the backs of the hands of 21 roofers applying asphalt [AI 1991; Hicks 1995]. All skin wipe samples were analyzed for 16 PAH compounds, including anthracene, B(a)P, chrysene, dibenz(a,h)anthracene, fluoranthene, naphthalene, and phenanthrene (see Table 4–10 in NIOSH [2000]). Only naphthalene (510 to 520 ng/cm^2) was detected.

5 METHODS FOR REDUCING ASPHALT FUME EXPOSURE

The following section provides information about work practices, engineering control methods, and personal protective equipment (PPE) that can be effective in reducing worker exposure to asphalt fumes at the kettle and during the application of hot asphalt to roofs. This information is presented according to the order of preference in the occupational safety and health hierarchy of controls [NSC 1996]. They range from control methods and work practices that can be followed on any roofing operation to those that reflect recently emerging approaches and technologies.

5.1 SUBSTITUTING LOW-FUMING ASPHALT

Low-fuming asphalt (i.e., the addition of small amounts of polymer to the asphalt) has been developed to reduce the emission of asphalt fumes from the kettle. Some of the polymer separates from the asphalt and forms a floating skim on the surface of the asphalt in the kettle. Results from initial field studies indicate that the skim formed on the surface of the asphalt dramatically reduces fume emissions and subsequently worker exposures [Franzen and Trumbore 2000]. According to one manufacturer, this technology works with any asphalt in any kettle and has no impact on product performance [Trumbore 2000].

The materials tested to date included asphalts containing polymer (either polypropylene or a blend of polypropylene and ethylene vinyl acetate copolymer) in amounts that are 0.3% to 1% of the asphalt by weight [Franzen and Trumbore 2000]. The polymer is either contained in the packaging material (meltable) that surrounds the asphalt keg or introduced during manufacturing of the roofing asphalt.

Studies in a controlled pilot plant setting showed average reduction in asphalt fume emissions (measured by high-volume-area samplers positioned directly above the kettle) of 89% for total particulates and 92% for benzene solubles [Franzen and Trumbore 2000]. PBZ exposures of a kettle operator were reduced by 84%, measured as benzene solubles. In addition, the use of the low-fuming asphalt negated the significant emission-increasing effects of higher temperatures that characterize conventional roofing asphalts.

The results of ongoing field investigations conducted in concert with NIOSH have thus far confirmed the pilot plant studies. The results to date show 70% to 88% reductions in asphalt fume emissions and 80% to 90% reductions in PBZ exposures of kettle operators [Franzen and Trumbore 2000]. In addition, recent unpublished data suggest that use of a low-fuming asphalt may reduce asphalt fume exposure to rooftop workers [Owens Corning 2000].

5.2 KETTLE SELECTION

Job-planning, setup, and advance worksite preparation are important considerations in minimizing worker exposure to asphalt fumes. The appropriate size of kettle should be selected to meet the demands of the job. Use of a kettle with inadequate capacity for the job will require the lid to be opened more frequently than necessary to ensure adequate quantities of heated asphalt to support the roofing work. Frequent opening of the lid will result in (1) more frequent worker exposure to asphalt fumes, (2) inconsistent asphalt temperatures that affect the application and quality of the asphalt, and (3) the need to heat the asphalt to unnecessarily high temperatures. For some jobs, it may be appropriate to use the tanker that delivers the asphalt instead of a kettle. The use of a tanker instead of a kettle can reduce fume emissions for jobs in which a large quantity of asphalt is used.

5.3 STEPS TO ISOLATE THE PROCESS AND MINIMIZE GENERATION OF FUMES

5.3.1 Placing the Kettle at the Worksite

The location of the kettle can have a significant effect on asphalt fume exposures to workers. When placing the kettle, take the following steps:

1. Minimize the distance from the kettle to the rooftop and use an insulated hot pipe to transfer the hot asphalt to the roof and avoid an unnecessary increase in the asphalt temperature at the kettle.

2. Set the kettle on level ground to avoid spilling asphalt or tipping over the kettle.

3. Place the kettle where the operator and other workers will be least exposed to the fumes—for example, downwind from the workers.

Regardless of location, the kettle should always be positioned with the inside of the lid facing away from the building (so that fume emissions are released away from the building when the lid is open).

The kettle should also be placed to minimize the risk of exposing building occupants to asphalt fumes. Therefore, place the kettle away from air intake vents, doors, and windows. Note also that some local fire safety codes may require the kettle to be located a minimum distance away from building walls and/or other combustible surfaces. Always check with the building manager to ensure that the air intake system is off and that covering the intakes will not cause damage to the ventilation system. If possible, work during off hours and give the building occupants a few days of notice before starting the job. Close and cover all building air intakes.

Because the kettle is the major source of asphalt fume exposure, restrict access to the area immediately surrounding the kettle. Mark the area with warning tape, traffic cones, and/or signs. The restricted area should be large enough to keep the public away from contact with the kettle or the asphalt and to allow sufficient space for the kettle operator to work. Restricting access also reduces the risk of burns to workers and bystanders and makes it less likely that vehicles or other equipment will unintentionally be permitted into the area.

5.3.2 Maintaining Asphalt Temperature in the Kettle

The following work practices and fume reduction techniques at the kettle are important for (1) maintaining the asphalt at the desired temperature for application, (2) reducing the risk of fires and explosions, and (3) minimizing fume generation and worker exposure. Also, asphalt kettles should have tight-fitting lids and should be closed during normal operations when asphalt is not being loaded.

To ensure reasonably accurate asphalt temperature readings at the kettle, follow these work practices:

1. Before starting the job, visually inspect the temperature-related equipment and controls such as thermometers, thermostats,

and automatic shut-off mechanisms to assure that they are in good working condition.

2. Make sure that the lid fits tightly.

3. Calibrate kettle thermometers and thermostats at least monthly or more often if recommended by the manufacturer.

4. Follow the manufacturer's recommendations for cleaning and maintaining thermostats, automatic shut-off controls, and other mechanisms that regulate the firing tubes.

5. Take temperature readings after skimming the asphalt.

6. If the kettle is controlled manually, monitor the temperature of the asphalt at least every 30 min.

7. Take manual temperature readings using a stem thermometer inserted just below the surface of the asphalt.

8. Verify temperature readings with the temperature gauge on the kettle by using a hand-held or infrared thermometer. When using an infrared gun, point it at a freshly disrupted asphalt surface to get a true reading.

As a generally accepted practice, the kettle temperature should initially be set at 50 °F (28 °C) above the EVT and then adjusted as needed to ensure that the EVT is maintained at the point of application on the roof. However, the kettle temperature should be kept at least 25 °F (14 °C) below the flash point temperature at all times. Maintaining the lowest possible asphalt temperature in the kettle will reduce the amount of fume generated and have quality benefits in reduced fallback and reduced coke/carbon buildup in the kettle.

When opening the kettle lid to refill the kettle, fill it to the maximum recommended fluid level. The kettle operator should chop asphalt kegs into manageable pieces before the refill operation to shorten the time needed to have the kettle lid open during refilling. These steps will help to maintain a constant asphalt temperature in the kettle, minimize the release of asphalt fumes, and reduce fume exposure to the kettle operator and other workers.

5.3.3 Applying Asphalt on the Roof

Many of the rooftop machines used to transport and apply the hot asphalt can also be insulated or covered, thereby reducing heat loss as well as the emission of asphalt fumes. Hot luggers, used to transport hot asphalt from the supply line to the area of application, typically have a capacity of 55 gal and can be insulated and covered. During this transfer from the hot lugger, using the draw-off valve/spigot at the proper height will help to avoid splash hazards and reduce heat loss. Felt-laying machines also carry a substantial reservoir of hot asphalt (typically, 40 to 49 gal), and some are insulated with lid covers. However, it is impractical to cover mop carts used for hot mop application of the asphalt, since the mop must constantly be moved in and out of the hot asphalt.

Workers applying hot asphalt on the roof should work upwind whenever possible to reduce their exposure to asphalt fumes. Operations involving filling or refilling of hot luggers, mop carts, buckets, and other containers of asphalt (such as those on mechanical asphalt spreaders or felt-laying machines) should also be conducted while standing immediately upwind of the operation whenever possible. Any lids or covers on containers of hot asphalt (such as those on hot luggers, mechanical spreaders, or felt-laying machines) should remain closed except during refilling operations. Buckets of hot asphalt should be no more than three-quarters full and should have half lids to reduce spillage. Workers should carry buckets on the down-roof side, and they should always use a twisting motion to unstick buckets and mops. For work in partially confined or poorly ventilated spaces (such as under eaves), fans may be an effective way to circulate the asphalt fumes away from the work area. If fans are used, they should be grounded and kept out of walking paths and any areas where contact with hot asphalt or liquids may occur.

5.4 CONTROL DEVICES FOR REDUCING ASPHALT FUME EMISSIONS

Asphalt fume emissions from the kettle can be reduced by maintaining a constant asphalt temperature in the kettle and preventing the release of fumes by the use of various control methods. A variety of thermostatically controlled heating systems are available to maintain a set asphalt temperature in the kettle. In addition, kettles are often constructed of double walls with thermal insulation between the walls; they may also have double lids to help maintain a constant temperature. Pumping rates have also increased substantially and are now typically 60 gal/min compared with 35 gal/min in the 1970s. This higher pumping rate reduces heat loss between the kettle and the point of application.

Using insulation throughout the mechanical systems that transport the liquid asphalt from the kettle to the point of application will reduce the amount of heat lost and thereby allow the kettle to be operated at lower temperatures. Pipe-insulating materials include fibrous supply line insulation and high-temperature glass fiber insulation. Since the pipe-insulating materials also help maintain the asphalt temperature in the pipe, they also reduce clogging of the supply lines caused by cooling and solidifying the asphalt on the inside walls of the pipe.

Several types of emission control devices (including emission capture and destruction devices as well as load insertion devices) have been introduced for use on kettles to reduce fume exposure. Emission capture and destruction devices consist of a vent or exhaust system that evacuates fumes from the headspace inside the kettle to a capture or destruction device. These devices often include afterburners, reburners, filters, and condensation systems. Most of these systems draw fumes from the headspace inside the kettle, thereby reducing the concentration of asphalt fumes inside the headspace. However, if the asphalt in the kettle is at a temperature that generates sufficient combustible vapors to exceed the UEL, these emission control systems may inadvertently lower the concentration of the asphalt fumes into the explosive range. Therefore, appropriate control devices are needed to monitor and maintain the asphalt fume concentration in the kettle headspace below the LEL. Also, steps need to be taken to prevent the airflow from causing coke to smolder and become an ignition source in the kettle headspace.

Controls (i.e., damper/flue) designed to regulate the airflow are being evaluated. In the meantime, prevent the potential for creating an explosion and fire risk by avoiding overheating of the asphalt, keeping the asphalt fume concentration in the headspace of the kettle below the LEL, and eliminating ignition sources.

Some afterburner systems use an open flame that can act as an ignition source. The ignition risk associated with the afterburner can be reduced by using flame arrestors, but these are prone to clogging and may not be sufficiently reliable to work effectively under actual operating conditions.

Another potential problem is coke or carbon buildup on the firewall of the kettle resulting from overheating of the asphalt. When a kettle is operated at high temperatures, this buildup can become so hot that it will glow red and act as an additional ignition source.

In systems that do not use afterburners or reburners, other potential ignition sources include the heating tube vent stack or flue. Kettle heating tubes generally run lengthwise through the vessel, then they turn and pass vertically through the kettle headspace to vent above the top deck of the kettle. In some situations, the asphalt itself can become an ignition source (i.e., if the asphalt temperature reaches at least 600 °F [316 °C]).

In addition to incineration, another method of reducing asphalt fume emissions is filtration. This newly emerging technology uses a series of filters, including high-efficiency particulate air (HEPA) filters and activated carbon to capture and filter particulates and vapors from the asphalt fume.

Loading devices provide another means of reducing the emission of asphalt fumes from the kettle. These devices allow the kettle operator to refill the kettle without opening the lid. Designs include mail slot openings and rotating loading drums that drop the solid asphalt into the kettle. Since all of these devices must be located above the liquid level in the kettle, they increase the headspace above the liquid asphalt. Although increasing the headspace in the kettle does not necessarily increase the risk of explosion, it can significantly increase the size of the explosion. In addition, these devices effectively reduce the usable capacity of the kettle. This reduction may create an incentive to overheat the asphalt in some circumstances, such as when the kettle operator needs to melt the asphalt more quickly to meet the needs of the rooftop crew for hot asphalt. Another difficulty with loading devices may arise from the inability of the kettle operator to evenly distribute the new asphalt as it is added to the hot asphalt already in the kettle. This situation can lead to "pyramiding" of the newly introduced (cold) asphalt in the kettle's heating vessel. Pyramiding may cause the loading device to operate incorrectly and may also create "cold spots" that could cause the kettle thermostat to heat the asphalt to excessively high temperatures. If not maintained properly, loading devices can also become clogged, necessitating the opening of the kettle lid so that the solid chunks of asphalt can be moved out of the way of the loading door. The opening of the kettle lid allows the release of additional asphalt fume into the work environment.

5.5 TRAINING AND EDUCATION

Workers should be trained in the use of good work practices for reducing exposure to asphalt fumes. They should also be provided with appropriate educational materials informing them of the potential hazards associated with working with asphalt.

5.6 USE OF PPE

5.6.1 Personal Protective Clothing and Gear

Proper PPE includes cuffless long pants and long-sleeved shirts made from natural fibers (avoid manmade organics such as polyester), nonskid shoes or boots with leather uppers that cover the ankles, safety glasses with side shields or goggles for rooftop workers whose eyes are sensitive to the fumes, face shields for kettle operators, and hard hats and leather gloves for all workers. Wearing PPE primarily protects workers against the risk of asphalt burns, but it can also reduce dermal contact with asphalt and asphalt fumes.

5.6.2 Respiratory Protection

Respirator use may be called for if available engineering controls and work practices are ineffective in controlling asphalt fume exposures to concentrations below the NIOSH REL of 5 mg/m^3 (total particulates measured as a 15-min ceiling) or applicable State or Federal standards. However, because respirator use can introduce new safety hazards in roofing work, respirator use should be the last resort for controlling exposures. When respiratory protection is provided, all applicable OSHA requirements should be followed in accordance with a written respirator program, including the use of NIOSH-approved respirators (see Appendix B), training, fit-testing, medical approval, and proper inspection, cleaning, maintenance, repair, and storage of respirators [29 CFR* 1910.134].

Code of Federal Regulations. See CFR in references.

6 RESEARCH NEEDS

The following research efforts should contribute to the reduction of worker exposure to asphalt fumes during the application of hot asphalt to roofs:

- Continue to evaluate the various types of asphalt kettles and determine what types of engineering controls and design configurations provide optimal reductions in asphalt fume exposure.
- Investigate alternative methods for feeding asphalt into the kettle to reduce the need for and frequency of lifting the kettle lid.
- Continue to evaluate the efficacy of low-fuming asphalts for reducing asphalt fume exposures at the kettle and on the rooftop.
- Investigate all sources of asphalt fume exposure during the application of hot asphalt to roofs and determine what types of changes in engineering control methods and work practices can be instituted to reduce such exposures.
- Conduct field studies to determine fume composition (e.g., PAHs, total particulates, soluble fractions) and concentrations at different asphalt temperatures.

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APPENDIX A

ASPHALT FUME EXPOSURES FOR VARIOUS OCCUPATIONS DURING ROOFING OPERATIONS

Table A– 1. Asphalt fume exposures for various occupations during roofing operations

References	Occupation	Source of exposure	Samples[*] Number	Samples[*] Type	Exposure concentration (mg/m^3)[†] Range		Geometric mean		Arithmetic mean	
Hervin and Emmett 1976	Hot asphalt machine operator/carrier	Roofing operation	6	Cyclohexane solubles	<0.02–0.19		0.050		0.082	
Brown and Fajen 1977a	Kettleman, felt layer	Asphalt heating and mopping	1	Benzene solubles	—[‡]		0.75	f[§]	0.75	f
					—		0.04	s	<0.04	s
	Felt layer		2	Benzene solubles	0.35–1.3	f	0.67	f	0.825	f
					<0.04–0.23	s	0.096	s	0.14	s
	Foreman, mopper		1	Benzene solubles	—		0.49	f	0.49	f
					—		0.12	s	0.12	s
	Felt tacker		1	Benzene solubles	—		1.1	f	1.1	f
					—		0.16	s	0.16	s
Brown and Fajen 1977b	Felt layer	Asphalt heating and mopping	2	Benzene solubles	0.08–0.78	f	0.25	f	0.43	f
					<0.04–0.35	s	0.12	s	0.20	s
	Foreman		1	Benzene solubles	—		2.1	f	2.1	f
					—		0.15	s	0.15	s
Brown and Fajen 1977c	Felt machine operator, mopper	Application of hot roofing asphalt	2	Benzene solubles	0.17–2.5	f	0.65	f	1.3	f
					0.22–0.47	s	0.32	s	0.35	s
	Hot asphalt carrier		1	Benzene solubles	—		0.57	f	0.57	f
					—		0.16	s	0.16	s

See footnotes at end of table. (Continued)

Table A–1 (Continued). Asphalt fume exposures for various occupations during roofing operations

References	Occupation	Source of exposure	Samples* Number	Samples* Type	Exposure concentration (mg/m³)† Range	Geometric mean		Arithmetic mean	
Brown and Fajen 1977c (continued)	Mopper		1	Benzene solubles	—	0.38	f	0.38	f
					—	<0.04	s	<0.04	s
	Felt layer		1	Benzene solubles	—	0.17	f	0.17	f
					—	0.08	s	0.08	s
	Asphalt tank operator		1	Benzene solubles	—	<0.11	f &s	<0.11	f & s
Puzinauskas l979	Kettleman	Type III roofing asphalt (low and high volatility)	6	Total particulates	1.3–12.5	2.6		3.7	
			6	Benzene solubles	0.91–6.9	1.8		2.3	
	Mopper		6	Total particulates	1.1–8.4	2.9		3.6	
			6	Benzene solubles	0.68–6.5	2.1		2.6	
	Paperman		6	Total particulates	0.35–3.3	1.2		1.5	
			6	Benzene solubles	0.25–2.4	0.8		1.1	
			3	Benzene solubles	1.4–6.9	2.5		3.3	
Tharr 1982	Kettleman	Asphalt heating and mopping	1	Cyclohexane solubles	—	0.28		0.28	
	Mopper		2	Cyclohexane solubles	0.16–0.17	0.17		0.17	
Reed 1983	Paper roller	Asphalt roofing	2	Benzene solubles	1.0–1.1	1.1		1.1	
	Mopper		1	Benzene solubles	—	0.9		0.9	
	Kettleman		2	Benzene solubles	1.2–1.2	1.2		1.2	

See footnotes at end of table. (Continued)

Table A–1 (Continued). Asphalt fume exposures for various occupations during roofing operations

References	Occupation	Source of exposure	Samples*		Exposure concentration (mg/m^3)†		
			Number	Type	Range	Geometric mean	Arithmetic mean
Brandt et al. 1985	Kettleman	Kettle emissions and bitumen spreading	2	Total particulates	4.1–6.4	5.1	5.3
			2	Benzene solubles	3.5–5.4	4.3	4.5
	Felt layers		7	Total particulates	0.5–1.7	—	1.3
			7	Benzene solubles	0.2–1.1	—	0.7
Carson 1986	Roof-level workers (laborer, mopper, carrier, etc.)	Application of an asphalt built-up roof	16	Acetonitrile solubles	0.04–2.7	0.16	0.34
	Ground-level workers (kettleman)		3	Acetonitrile solubles	0.04–0.83	0.27	0.49
Zey et al. 1988	Various (kettleman, laborer, etc.)	Application of asphalt roof	24	Benzene solubles	ND–1.4	—	0.39
			18	Total particulates	<0.02–1.0	—	0.54
Hicks 1995; AI 1991	Roofer	Roofing operation (temperature of product at fume source from 163 to 316 °C [325 to 600 °F])	12	Total particulates	0.04–2.2	0.36	0.58
			12	Benzene solubles	0.011–1.7	0.19	0.45
	Laborer		5	Total particulates	0.21–0.91	0.38	0.47
			5	Benzene solubles	0.17–0.62	0.3	0.34
	Mechanic		7	Total particulates	0.24–1.2	0.54	0.65
			7	Benzene solubles	<0.078–1.8	0.26	0.49

See footnotes at end of table.

(Continued)

Table A–1 (Continued). Asphalt fume exposures for various occupations during roofing operations

References	Occupation	Source of exposure	Samples* Number	Samples* Type	Exposure concentration (mg/m³)† Range	Geometric mean	Arithmetic mean
Hicks 1995; AI 1991 (continued)	Felt machine operator		7	Total particulates	0.57–2.5	1.0	1.3
			7	Benzene solubles	0.046–2.4	0.21	0.53
	Kettleman		4	Total particulates	0.36–1.6	1.0	1.2
			4	Benzene solubles	0.14–1.2	0.67	0.89
	Mopper		3	Total particulates	0.27–1.2	0.51	0.63
			3	Benzene solubles	<0.085–0.75	0.21	0.33
Schneider and Susi 1993; Susi and Schneider 1995	Kettleman	Asphalt roofing	1	Benzene solubles	—	21.8	21.8
			3	Total particulates	10.4–28.85	—	18
	Mopper		4	Benzene solubles	0.08–0.35	—	0.22
			4	Total particulates	<0.03–3.66	—	1.14
	Roof-level workers:						
	Cutting insulation board		2	Benzene solubles	0.35–0.92	—	0.63
			2	Total particulates	0.52–0.97	—	0.75
	Carrying buckets of hot asphalt		2	Benzene solubles	0.51–1.89	—	1.46
Exxon 1997; Gamble et al. 1999	Foreman	Application of roofing asphalt (4 work sites)	6	Total particulates	0.04–0.77	0.22	0.33
			6	Benzene solubles	0.04–0.34	0.12	0.16
	Kettleman		4	Total particulates	0.04–0.72	0.27	0.41
			4	Benzene solubles	0.04–0.48	0.15	0.21

See footnotes at end of table. (Continued)

Table A–1 (Continued). Asphalt fume exposures for various occupations during roofing operations

References	Occupation	Source of exposure	Samples*		Exposure concentration (mg/m^3)†		
			Number	Type	Range	Geometric mean	Arithmetic mean
Exxon 1997; Gamble et al. 1999 (continued)	Laborer (misc.)		7	Total particulates	0.06–0.35	0.17	0.25
			7	Benzene solubles	0.03–0.22	0.06	0.07
	Mop man		7	Total particulates	0.1–0.54	0.30	0.34
			7	Benzene solubles	0.6–0.39	0.16	0.19
	Roof laborer		36	Total particulates	0.03–2.73	0.44	0.73
			34	Benzene solubles	0.03–1.23	0.13	0.23

*Solvents such as cyclohexane and acetonitrile have been used in place of benzene to measure the soluble fraction of a particular matrix. Because the extraction ability of these solvents varies, results are not comparable.
†Sampling periods ranged from <1 to 8 hr, with most samples >6 hr.
‡Dash indicates that information was not provided.
§Abbreviations: f=filter; ND=not detected; s=sorbent tube.

APPENDIX B
RESPIRATORS

Constantly changing environmental and worksite conditions during application of hot asphalt to roofs may result in fluctuating airborne asphalt fume concentrations for exposed workers. Respiratory protection may be needed if available engineering controls and work practices are ineffective in keeping asphalt fume exposures below the NIOSH REL of 5 mg/m^3 (total particulates measured as a 15-min ceiling) or applicable State or Federal standards. If respirators are required at the worksite, the employer is responsible for ensuring that respirators are NIOSH approved and that all applicable OSHA regulations pertaining to the implementation of a respirator program are followed. Important elements of these OSHA regulations include the following [29 CFR 1910.134]:

- An evaluation of the worker's ability to perform the work while wearing a respirator
- Regular training of workers
- Periodic environmental monitoring
- Respirator fit-testing, maintenance, inspection, cleaning, and storage
- Periodic changes of cartridges
- Cartridge testing for service life

No NIOSH-approved respirator filter cartridge or canister exists specifically for asphalt fumes or aerosols. But the following respirators are recommended for use:

- Any half-facepiece, air-purifying respirator equipped with a combination R100 or P100 filter and an organic vapor (OV) cartridge, or
- Any powered, air-purifying respirator with a hood, helmet, or loose-fitting facepiece equipped with a combination HEPA filter and OV cartridge.

ote: The appropriate respirator filters are R100, P100, or HEPA, as listed under 42 CFR 84 [NIOSH 1996]. The appropriate OV cartridge or canister should contain a charcoal sorbent. This type of protection (combination filter/OV cartridge) may also be used when there is a potential for exposure to dusts containing coal tar particles or asbestos.

Other types of respirators may be required under certain conditions (e.g., work in confined spaces) [NIOSH 1987a,b]. A comprehensive assessment of workplace exposures should always be performed to ensure that the proper respiratory protection is used.

Occasionally, workers may voluntarily choose to use respiratory protection when asphalt fume exposures are below the NIOSH REL or applicable Federal and State standards. When respirators are used voluntarily by workers, the employer needs only to establish those respirator program elements necessary to assure that the respirator itself is not a hazard [29 CFR 1910.134]. The exception is that filtering facepiece respirators (e.g., any 95- or 100-series filter) can be used without a respirator program when used voluntarily.