

Evaluating Engineering Controls During Asphalt Paving Using a Portable Tracer Gas Method

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INTRODUCTION

Annually, an estimated 300,000 workers perform asphalt highway and street construction in the U.S. Hot mix asphalt (HMA) paving material typically consists of 95% mineral aggregate (rock, sand, and gravel) and only 5% asphalt cement, which is the glue that holds the aggregate together. The major constituents of asphalt cement are asphaltenes, resins, and oils which consist of saturated and unsaturated hydrocarbons. For many of the chemical constituents present in asphalt fume, there are no relevant exposure criteria. The current NIOSH recommended exposure limit (REL) for asphalt fume is 5 milligrams per cubic meter (mg/m³) for a 15-min ceiling value. A Threshold Limit Value (TLV[®]) of 5 mg/m³ for an 8-h time weighted average (TWA) has been set by the American Conference of Governmental Industrial Hygienists (ACGIH). The Occupational Safety and Health Administration (OSHA) does not currently have a regulation specifically for exposures to asphalt emissions.

Limited data exist concerning the level of exposure and any related health effects for asphalt paving workers. Some workers have reported acute health effects including breathing difficulty; bronchitis; burning of the eyes, nose, throat, and skin; headaches; and nausea. Workers can also suffer ill effects from hot outdoor environments and the heat coming from the asphalt which is typically around 150°C.

Because of the questions and concerns about exposure risk to 300,000 workers, the National Asphalt Pavement Association (NAPA) initiated efforts with five asphalt paver manufacturers, representing more than 80% of the highway-class paver market in the U.S.A., to independently design engineering controls for their respective pavers. Through an agreement with the Federal Highway Administration, NIOSH assisted the manufacturers with their prototype designs, then independently evaluated each prototype's performance both in a controlled environment and during paving operations. The partnering also included labor organizations, and other parties related to this industry.

THE PAVING PROCESS

At the HMA plant, mineral aggregates are proportioned according to a mix design or "recipe", then heated and coated with asphalt cement to form a hot, homogeneous, asphalt paving mixture. The HMA is transported from the mixing plant by truck and is transferred to the receiving hopper of the paving machine either directly or via an optional material transfer vehicle.

The asphalt paving machine consists of two primary components: the tractor unit and the screed unit (Fig. 1). The tractor unit provides the locomotion for the paver. A receiving hopper on the front of the tractor receives the HMA from the material transfer vehicle. Two slat-conveyors transfer the HMA from the receiving hopper through conveyor tunnels and to the rear of the tractor where it falls to the prepared road surface. Screw augers, located at the back of the tractor, distribute the HMA across the width of the paving surface. The second component of the paving machine, the screed unit, follows directly after the screw augers and is similar to a heavy sled. The screed levels the HMA material and provides initial compaction and texture

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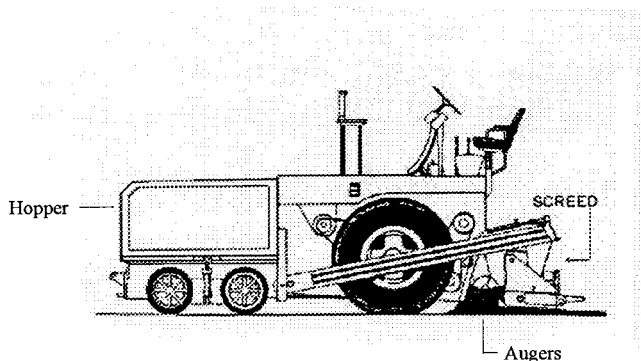


FIGURE 1. Asphalt paver.

to the paving surface. The paver is followed by a compactor to finish the process. Usually, HMA arrives at the paving site at temperatures between 120°–160°C.

When some asphalt cement modifiers are used, they increase the HMA's stiffness, thus requiring higher application temperatures for workability. The greater the temperature of the HMA, the greater the generation of fumes and vapors. During transport, the exposed HMA surface cools, creating a "skin" which tends to encapsulate the HMA and inhibits the release of fumes and vapors. During agitation of the HMA, the skin is disrupted, which greatly increases the release of fumes and vapors. There are two primary opportunities for HMA agitation to occur during the paving process: (1) when HMA is transferred into the hopper and (2) when HMA falls from the slat conveyor and is distributed by the augers. During preliminary field evaluations conducted at asphalt paving sites, the location which emitted the predominant amount of fume and vapor was determined to be within the auger area between the back of the tractor and the screed [NIOSH, 1995]. The asphalt paving process requires that the paving crew work at the point of asphalt application, where the HMA is distributed by the augers. The partners focused the development of engineering controls on the point of application because it was the highest source of fume generation and workers were closest to this part of the process.

METHODS AND RESULTS

NIOSH engineers developed a protocol that divided the project into two phases. Phase I evaluations were conducted at each participating paver manufacturing plant. Each of the manufacturers developed its own prototype design(s) for evaluation. While each manufacturer's design was unique, all of the engineering control designs incorporated local exhaust hoods above the auger, exhaust fans, vertical exhaust stacks, and the associated duct material. Some of the prototype designs provided additional enclosure around

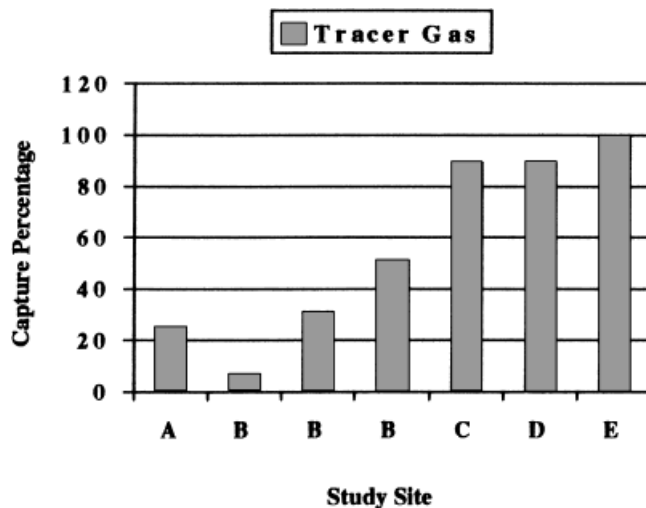


FIGURE 2. Stationary capture efficiencies using tracer gas.

the auger area. During Phase I, a tracer gas, sulfur hexafluoride (SF_6) was released in the auger area to enable quantification of the capture efficiency and exhaust flow rate for each prototype under prescribed indoor stationary conditions. Individual stationary capture efficiencies averaged from 7 to 100% (Fig. 2). The tracer gas testing protocol successfully revealed deficiencies in prototype designs which may have gone undetected. Some manufacturers used these evaluation results to compare performances among multiple hood designs. These stationary performance evaluations proved to be a valuable method to identify strengths and weaknesses in individual designs and subsequently optimize those designs prior to more expensive analytical field studies.

The Phase II evaluations were conducted at asphalt paving sites. Prototype controls, which were improved based on Phase I results, were installed on each participating manufacturer's paver. The evaluation consisted of aerosol, organic vapor, and surrogate contaminant monitoring during the paving process. The focus of this paper will be on the portable tracer gas method and its effectiveness and usefulness in the evaluation of ventilation control systems. The tracer gas method, originally designed for the Phase I evaluation, was modified to be field portable to meet the needs of the Phase II part of the study. Tracer gas was released from four locations above the auger during actual paving operations and measurements were made to quantify the capture efficiency of the system. Capture efficiencies measured during paving by using the SF_6 technique averaged from 83 to 99% (Fig. 3).

Industrial hygiene area air samples were also taken to quantify the capture of asphalt fume with and without the control system turned on. Samples were collected above the auger area and were analyzed for total polycyclic aromatic compounds (PAC) as a measure of asphalt emissions.

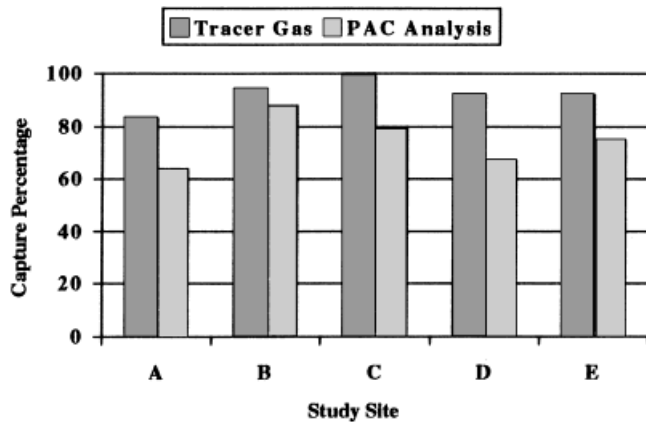


FIGURE 3. Comparison of tracer gas and PAC capture percentage results.

Capture efficiencies measured by the PAC technique averaged from 64 to 88% (Fig. 3).

DISCUSSION

Both the SF₆ and the PAC techniques showed significant capture efficiencies for each of the controls tested. The SF₆ technique showed consistently higher efficiencies than the PAC technique. There are two plausible hypotheses for this result. First, the four points used to distribute the SF₆ may have inadequately distributed the tracer gas, resulting in a bias of higher capture of the SF₆ over that of the PAC. A technique to distribute the SF₆ across the entire auger area, similar to the Phase I procedure, was attempted using high velocity orifices; however, during HMA paving, the orifices occasionally came in contact with

the HMA which caused partial blockage and hampered the distribution of SF₆. Second, PACs could be migrating into the auger area from other sources such as from the truck dumping or from the asphalt mat behind the screed, resulting in a bias of lower capture of PAC.

CONCLUSIONS

The tracer gas method was shown to be a very versatile technique for evaluating the effectiveness of paving machine ventilation systems under controlled conditions as well as under very difficult environmental conditions. Tracer gas results could be obtained quickly, allowing prompt feedback on the control's performance. In comparison, PAC samples, which were analyzed in a laboratory, took three weeks to process.

Care must be taken to distribute the tracer gas in a way that the gas will act as a surrogate for the contaminant of interest. Even though there appears to be a bias in the tracer gas results, the relative results of this technique can be used to find design deficiencies and guide in the optimization of control designs of paving machines.

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